SUNSHOT industries

Barcaldine Renewable Energy Zone

A model for regions in transition

This publication has been compiled by the Sunshot Zero Carbon Futures division of Sunshot Industries Pty Ltd.

Note: This document was authored based on findings in initial Barcaldine site commercial and technical feasibility studies and will be subject to change over time.

The Sunshot Industries mission is to enable competitive manufacturing in Australia, with a sustainable energy cost advantage – re-energising and decarbonising Australian industry.

Sunshot Industries invests transformation capital and knowhow in energy intensive businesses, seeking to exit once the business is on a cost-advantaged, low carbon footing.

It targets underperforming sectors with clear prospects to establish a competitive position in the top quartile of global industry, and to deliver substantial C02e abatement.

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Executive Summary

Queensland's exceptional solar and good wind resources combined with high per capita biomass potential is an advantage for energy intensive businesses in the emerging low-carbon world economy. With supporting infrastructure and incentives to deliver globally competitive energy and biochemical inputs at scale, rural and provincial Queensland has natural advantages for making green hydrogen, processing minerals and biomass and a number of other industrial activities that do not currently have a large place in our economy. Production of ammonia from hydrogen from electrolysis using renewable electricity together with carbon dioxide drawn from combustion of bioenergy can eliminate CO2 emissions from the nitrogenous fertiliser urea. The development of net zero emission supply chains will be important for future access of Queensland farm produce to high value Australian and international markets. There are also opportunities for production of urea and other zero emissions industrial products in a Barcaldine Renewable Energy Zone Industrial Precinct (BREZ).

The Barcaldine Renewable Energy Zone: a model for regions in transition report was commissioned by Department of Environment and Science, Communities in Transition pilot program – to demonstrate long term economic development pathways for regional Queensland. Using the Barcaldine Renewable Energy Zone (BREZ) as a case study, with a focus on energy system optimisation, biomass and minerals processing and fertiliser production, this report provides a model for growth in sophisticated manufacturing and sustainable development in regional areas.

The Barcaldine region has significant advantages as a renewable energy industrial hub development and demonstration. It has good supporting infrastructure including a 132 kV transmission line connecting to the NEM, good road and rail connection, an active airport and proximity to the Ergon network centre with a gas pipeline connection, and strong and committed local government.

The Barcaldine Regional Council and the Remote Area Planning and Development Board (RAPAD) have worked in partnership with Sunshot Industries to develop the BREZ model. Federal funding through the Northern Australian Infrastructure Fund and support from the Queensland Department of State Development, Infrastructure, Local Government and Planning under the Industry Partnership Program will be crucial to turning the BREZ project from feasibility study to reality. Current indications of Commonwealth and State support are positive.

This document outlines a scenario for the future development of the Barcaldine Renewable Energy Industrial Zone (BREZ) as a prototype for zero emission business development in regional Australia. The scenario envisages regional economic benefits of $2.1 billion over ten years and around $5.4 billion over 30 years. In helping secure some 500 permanent jobs, with more in supporting services, it would return Barcaldine's population to or above historic peaks and fully utilise established town infrastructure for the first time in many years.

The proposed model provides BREZ tenants with an all-service site including long extendable leases and reliable and globally cost competitive green electricity and bio-chemical inputs. BREZ *anchor tenants* will focus on protected intensive horticulture, minerals processing and commercial scale green hydrogen urea production supplied by pyrolytic conversion businesses. Co-location will enable supply chain optimisation of significant biochemical inputs achieving cost reductions by up to 80%. The model will facilitate demonstration of leading-edge technologies, such as Green Distillation Technologies pyrolytic waste conversion process and Renergi's pyrolysis of municipal waste and mobile pyrolysis of biomass.

The business model is underpinned by a feasibility study of green hydrogen production, including as feedstock for co-located ammonia and urea production, at a highly competitive price, delivering costs for ammonia and urea production at prices that are competitive with long-term average levels for imports and are stable - delinked from the commodity price cycle. Optimisation of energy supply can further reduce costs.

To support Queensland's natural advantage in biomass for industry and storing carbon in soil, much research is required. The Land Carbon and Productive Plantation (LCPP) model that Sunshot Industries is developing with several major landowners in the Barcaldine region, will demonstrate the value of biomass for industrial use; how land carbon and biomass work for negative and zero emissions; and opportunities for exporting carbon credits and rewarding landowners for carbon sequestration. It will engage joint research amongst Commonwealth (principally CSIRO) and Queensland agencies (Department of Environment and Science and Department of Agriculture and Fisheries) and Universities. The Queensland Department of Agriculture and Fisheries decommissioned Rosebank research station near Longreach is highly suitable for the proposed research. Sunshot Industries intends to develop a proposal for basing the LCPP research at Rosebank if the BREZ receives necessary State approvals.

The BREZ is envisaged as a transformational model not just for Barcaldine but also for the State's regions, providing industrial activity, employment and incomes and inputs for agriculture and other local industries based on some of the world's best combinations of renewable energy potential. Successful delivery of this model would make Queensland a leader in decentralised global green industrial development.

Realising the greater opportunity for regional Queensland requires decadal commitment to developing supporting infrastructure. Overcoming the disadvantages of small-scale and isolation requires policy settings that encourage investment in infrastructure to provide access to Queensland's exceptional renewable energy resources. State planning and investment in conjunction with the Federal Government regarding enabling transmission and energy storage is required for the opportunity for the regions to be realised at scale. The BREZ experience will help de-risk future site selection and opportunities in other regional locations such as Longreach, Hughenden, Emerald, Moranbah and in the Darling Downs. Building on BREZ learnings, and working with the Commonwealth towards implementation of comprehensive carbon accounting will accelerate land holders' access to the carbon drawdown opportunity and expand their access to international voluntary and compliance markets for land-based offsets.

The local support in Barcaldine and from the seven Mayors of the Central West Remote Area Development & Planning Board (RAPAD) demonstrate the growing understanding in regional Queensland of the value of their renewable energy and biomass resources to diversify and secure their economic base into the future. Entrepreneurial innovation and resilience have shaped Queensland regions and it is this determination, along with enabling policy and strategic State and Federal investment, that will realise future prosperity for Queensland regions.

Background

Discussions leading to the concept of the Barcaldine Renewable Industrial Zone (BREZ) began in early 2017 when the seven Mayors of the Central West Remote Area Development & Planning Board (RAPAD) approached Sunshot Industries for advice on the potential for new industries to expand employment and incomes using the region's renewable resources. Company Chair, Professor Ross Garnaut, visited the region four times over the next three years and met with the regional mayors on two occasions in Brisbane. In identifying several promising industrial projects, it was decided to initially focus on development of one industrial zone. Barcaldine had the best prospects because it was the centre of east-west and north-south road networks; was on the east-west railway; had a substantial and active airport; was the centre of the central west power network and hosted the Ergon network centre with gas pipeline connection; was on the main NBN link from Darwin to eastern Australia; and shared the region's excellent solar energy resource and had opportunities for biomass and wind energy generation. Barcaldine has the best solar resource amongst all locations in eastern Australia with a substantial connection to the National Electricity Market's main grid. It was decided that success in one location would show the way to others and be followed by efforts to develop industrial zones in other shires.

The Department of Environment and Science *Regional Communities in Transition Pilot Program* has supported the further development of Barcaldine Renewable Energy Zone (BREZ) as a prototype for regional towns in transition, identifying social and environmental prosperity opportunities, as outlined in this report.

Commercial and technical planning has been advanced through the cooperation of the Remote Area Planning & Development Board (RAPAD), Barcaldine Regional Shire Council and Sunshot Industries Pty Ltd. The progress is described in this report. It is proposed that the BREZ would host Australia's first commercial scale green hydrogen/ammonia/urea plant. This report notes how aspects of the model could be applied in other regional centres which are facing similar transition opportunities and challenges.

Since its inception discussion has been held with industrial partners who would locate at the BREZ. Heads of Agreement have been signed with the 10 businesses that have agreed to invest in the industrial site, stating intention to locate at the BREZ, and outlining features of their projects: investment level; employment; and industrial requirements for energy, water, chemical inputs and freight.

This document lays out a model for the development of the BREZ with a particular focus on the integration of energy supply and green chemical processing of hydrogen, ammonia and urea.

The document begins with a brief overview of opportunities for renewable energy zones in supporting business development in Queensland, and the specific opportunity for Barcaldine, including a summary of the business model as developed by participants to date. Section 3 summarises the essential resource base that will underpin BREZ business in terms of energy, biomass and water supply. The following sections summarise BREZ business development feasibility studies undertaken by Sunshot Industries, Barcaldine Regional Council and the Central West Remote Area Planning & Development Board (RAPAD). Section 4 explores the feasibility of green hydrogen, ammonia, and urea supply chains, benchmarked against a targeted levelized cost of hydrogen. Section 5 shows how the cost basis for energy intensive chemical supply-chains can be significantly improved by optimisation of the energy system. Section 6 outlines a model for securing long-term sustainable biomass production. Several recommendations for further development are outlined in Section 7.

Business Model: Barcaldine Renewable Energy Zone

A model for regions in transition: summary of social and economic benefits

Regional Queensland's advantage in the emerging low carbon economy

Australia has by far the richest per capita solar and wind energy resources of any developed nation. The proximity of world-class solar resources, good wind resources and reliable access to water in several Queensland inland locations is unusual in Australia and the world (Figures 1a, 1b, 1c). Managed well, the cost of energy will be lower in Australia than in any other country in the zero-emissions world economy. Consequently, Queensland is well placed to attract industries where energy is a major input cost as the world realises the goals agreed at the Paris meeting of the United Nations Framework Convention on Climate Change in December 2015, and now being taken forward in the November 2021 meeting of the Convention in Glasgow.

With its exceptional mineral prospects, Queensland has the opportunity to build local mineral processing capability for commodities the demand for which is growing rapidly to meet the requirements of the world's energy and industrial adjustment to zero emissions: copper, zinc, manganese, aluminium as well as what the Quad Heads of Government meeting in Washington September 2021 called *critical minerals*--new energy commodities including silicon, cobalt, magnesium, nickel, lithium, vanadium, graphite, titanium and the rare earths.

Future supply chains in the net zero world will rely on *green hydrogen* produced using renewable energy in many industrial processes. With hydrogen necessary for production of ammonia for fertilisers and explosives, production of ammonia derivatives such as urea naturally gravitates towards low-cost renewable energy centres in Australia.

In addition to abundant solar and wind resources, Queensland's high per capita water availability and land acreage provide natural advantage in the production of biomass for industry. Biomass is a source of zero emissions energy, whether used directly or through use of bio-oil or biogas from pyrolysis. Bioenergy gasification technologies have evolved since 2017 to be of major importance in the US and Europe, where bioenergy and biofuel targets encourage uptake. Biomass can be used as an industrial input replacing coal, oil or gas. Converted into liquid fuels it will have especially high value in long distance civil aviation, for which low ratios of energy to mass make batteries and hydrogen fuel cells unsuitable. Biomass can provide a key input for production of zero emission nitrogenous fertilisers. The use of carbon dioxide derived from combustion of bioenergy with oxygen waste from electrolysis allows for zero emissions conversion of ammonia into urea.

Bio-sequestration in living plants and in soils from biomass growth or productive plantations, combined with other methods of drawing carbon into the land (application of biochar to soils, regenerative land management and reafforestation), also present a significant opportunity across large-acreages in regional Queensland. Queensland's Land Restoration Fund supports the growth of the carbon market in Queensland by valuing and paying for the additional environmental, economic and social co-benefits that are derived from carbon farming projects, as verified by the LRF Co-benefits Standard. The value of the opportunity increases with the price of carbon. Carbon prices in international voluntary and EU and UK compliance markets have risen rapidly in recent times to approaching $A100 per tonne of carbon dioxide, equating to over $350 per tonne of carbon in soils or plants.[1] This is near the economically rational price identified by credible economic models—that suggest that the price of carbon will rise over time at a rate corresponding to the interest rate (US Department of Energy, various years; Garnaut 2008). While the Australian compliance market has been artificially repressed, international arbitrage and expectations are providing an upward pressure evident in the rise from around $15 per tonne of carbon dioxide to around $23 over the past year.

Figure 1a: Eastern Australian wind power

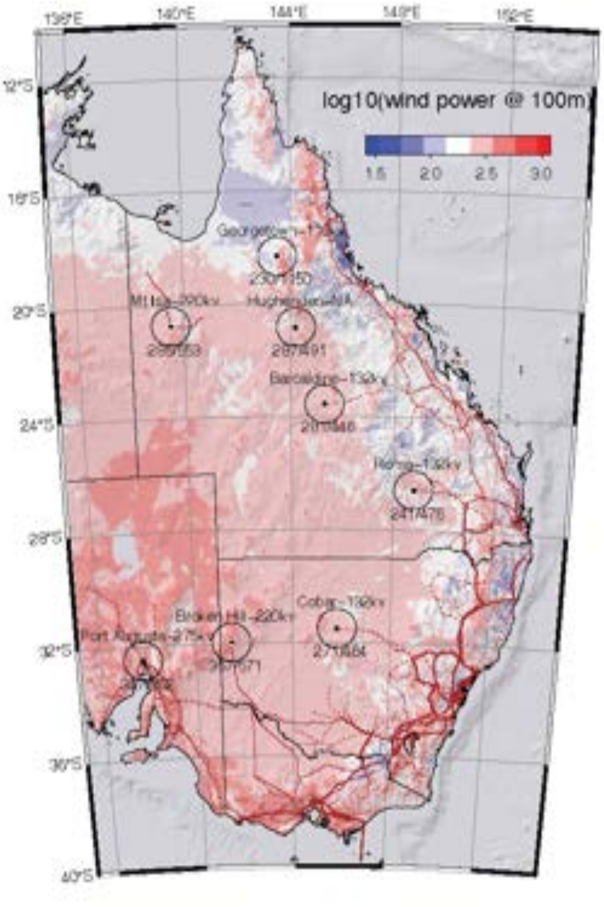
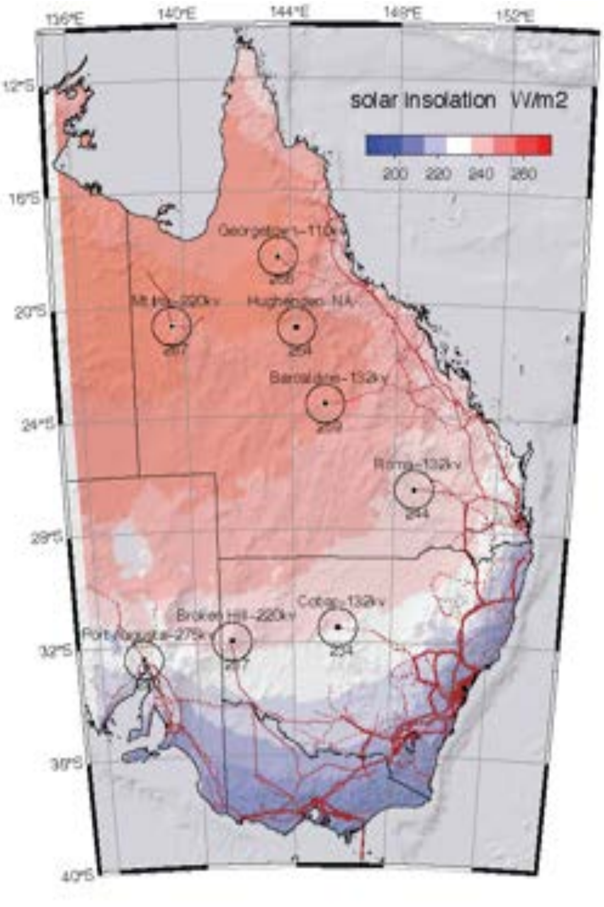


Figure 1b: Solar insolation



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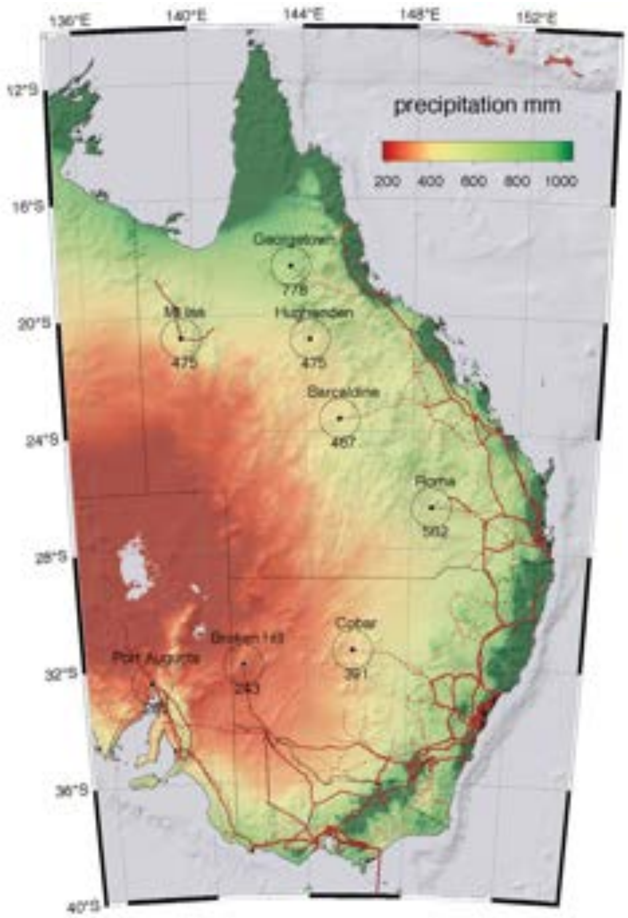
[1] https://www.pv-magazine.com/2021/05/13/eu-carbon-price-running-at-level-not-expected-until-next-year/

Figure 1c (below): Precipitation. Solid red lines show existing transmission with voltage greater than 300KV. Dashed red lines are existing transmission with voltage less than 300KV. Circles, radius 75 kms, show average resources for selected inland sites with grid connection (as well as Hughenden and Mount Isa). For wind power, both average and maximum wind power are reported.



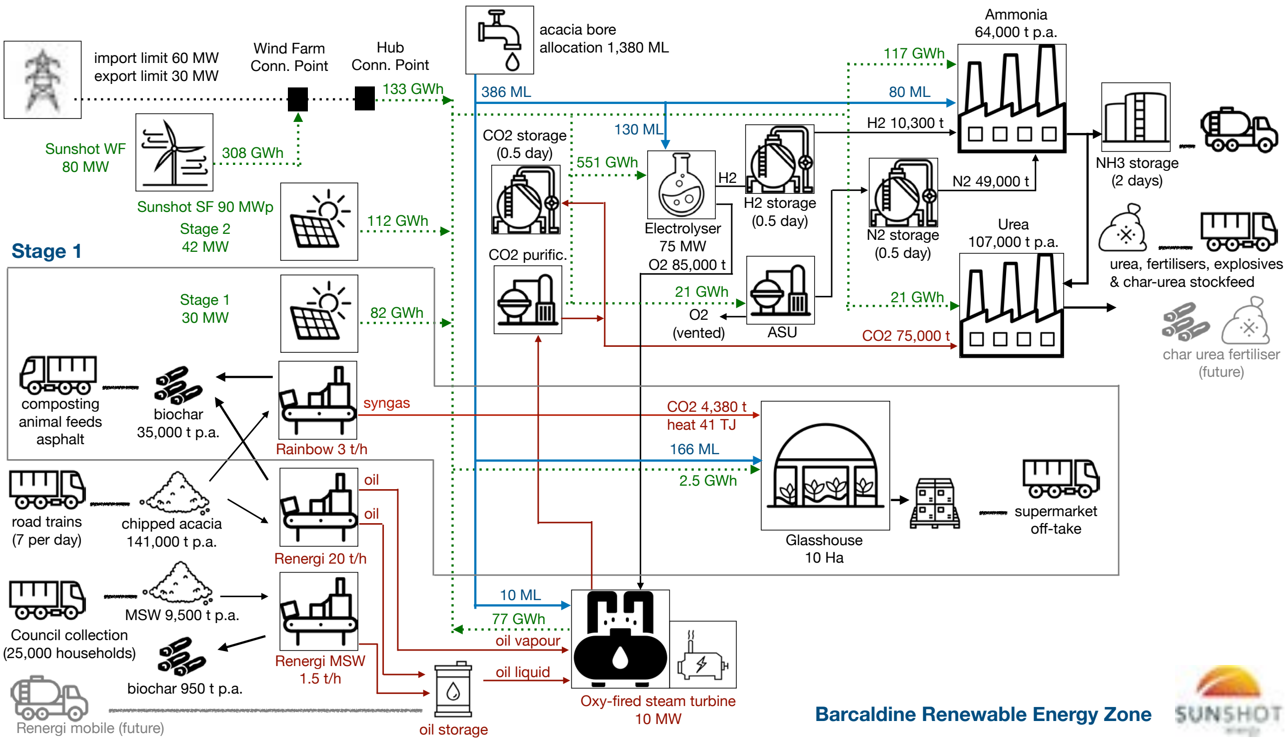
Renewable Energy Industrial Hubs – The Barcaldine Model

The Barcaldine Renewable Energy Industrial Hub (BREZ) takes advantage of Queensland's world class renewable energy resources and potential for biomass production. The BREZ will pioneer sophisticated zero emissions production of hydrogen, ammonia and urea, processing of minerals and intensive horticulture. The plan outlined here envisages a regional investment in 2021 dollar-terms of $2.1 billion over ten years, up to $5.4 billion over 20 years, securing around 500 new permanent jobs across ten new businesses.

Sunshot Industries and its sister company ZEN Energy will take responsibility for supplying renewable energy and hydrogen at highly competitive prices to the intensive horticulture ammonia, urea production as illustrated in Figure 2:

- **Hydrogen, ammonia to urea processing:** commercial-scale green hydrogen facility producing 60,000 tonnes p.a. of ammonia and 107,000 tonnes p.a. of urea.
- **Renewable electricity supply:** providing BREZ businesses (wholesale and retail) with some export sales to the Queensland grid, supplied by ZEN Energy.
- **Protected intensive horticulture:** including a large-scale horticulture under contract with national supermarket chains grown in 10 hectare greenhouse using sustainably sourced carbon dioxide and renewable energy.

Figure 2: Key aspects of the BREZ integrated ammonia, urea, intensive horticulture pipeline



In addition, the BREZ will host:

- **Mineral processing:** including a vanadium processing electrolyte plant capacity at 15MWh p.a. scaling up to 80-85MWH p.a. once the VECCO group's Julia Creek vanadium mine reaches full operating capacity. We are working towards locating a demonstration of a flow battery using locally processed vanadium at BREZ.

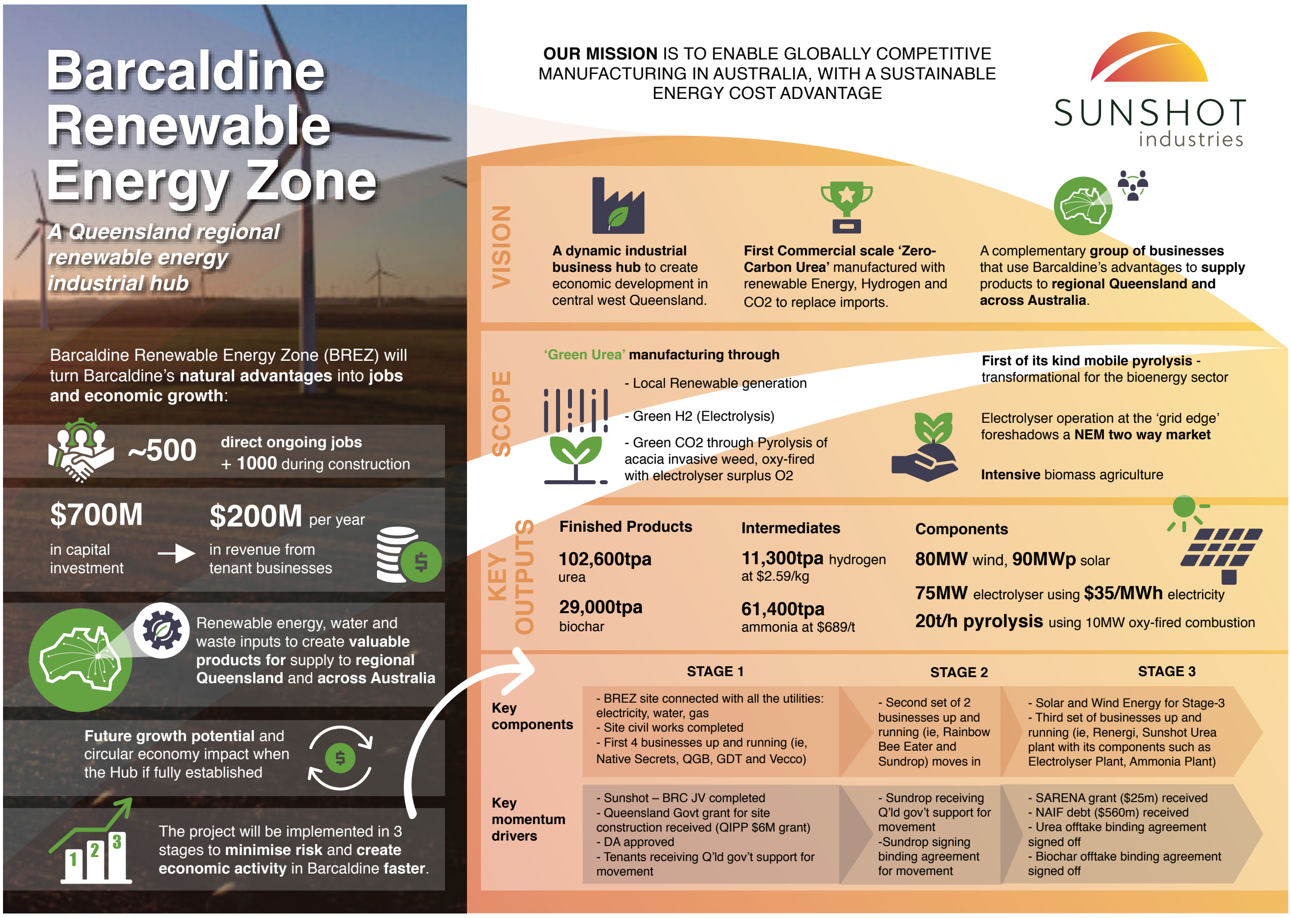
The initial development of BREZ will be staged (see Figure 3):

- **Stage 1:** involving ~$118 million dollars investment over 3 years from 5 businesses, generating 100 permanent FTEs and 190 construction jobs.
- **Stage 2:** involving ~$582 million dollars of private investment plus 600 construction jobs and 400 permanent FTEs over 5 years and including the development of a large-scale intensive horticulture business for an Australia-wide market, and Australia's first commercial scale green hydrogen urea plant.

In addition to the anchor businesses listed above, a range of other businesses have confirmed intent to locate in BREZ:

- **Rainbow Bee Eater (RBE):** which will use pyrolysis to produce char, bioenergy and carbon dioxide, with waste heat and carbon dioxide to supply intensive horticulture requirements.
- **Renergi:** which plans to use produce char and bio-oil from biomass using mobile pyrolysis technology, and char and oil from pyrolysis using municipal waste. Inputs will include municipal wastes (see Breakout Box- Pyrolytic waste conversion) and long-distance processing of biomass such as prickly acacia.
- **Green Distillation Technologies Corporation Limited:** which will use destructive distillation pyrolysis to produce a stable oil from used tyres, with recovery of steel scrap.
- **Gidgee Brothers:** which will produce barbecue grade charcoal from waste gidgee.
- **Native Secrets Pty Ltd:** which will manufacture essential oils employing 6-12 Indigenous workers including labour for native cypress collection.

Figure 3: Sumary of BREZ development staging and anticipated benefits



The fundamental offering of the BREZ industrial zone is an all-services industrial site providing highly reliable and cost-competitive (and in the case of electricity, globally cost-competitive) access to: long and extendable leases over land; intermodal road, rail and air transport and electronic communications; electricity, water, sewerage, waste management, security; and regulatory approvals.

BREZ *all-services* will be provided by a joint venture between Sunshot and Barcaldine Regional Council with RAPAD support. The Sunshot-Barcaldine-RAPAD JV will invest in the precinct, funded by a combination of capital grants from the State Government, debt and equity capital.

Sunshot will underwrite access to electricity that is globally competitive in reliability and price, which is critical to attracting many investments.

In addition to its primary goal of providing businesses with an all-service industrial site, the BREZ is envisaged as a prototype for net-zero regional development opportunity in regional Australia. The production of hydrogen, ammonia and urea with a highly innovative zero-carbon supply chain at globally competitive prices, will position Queensland as a leader in the nascent Australian hydrogen market.

PYROLYTIC WASTE CONVERSION

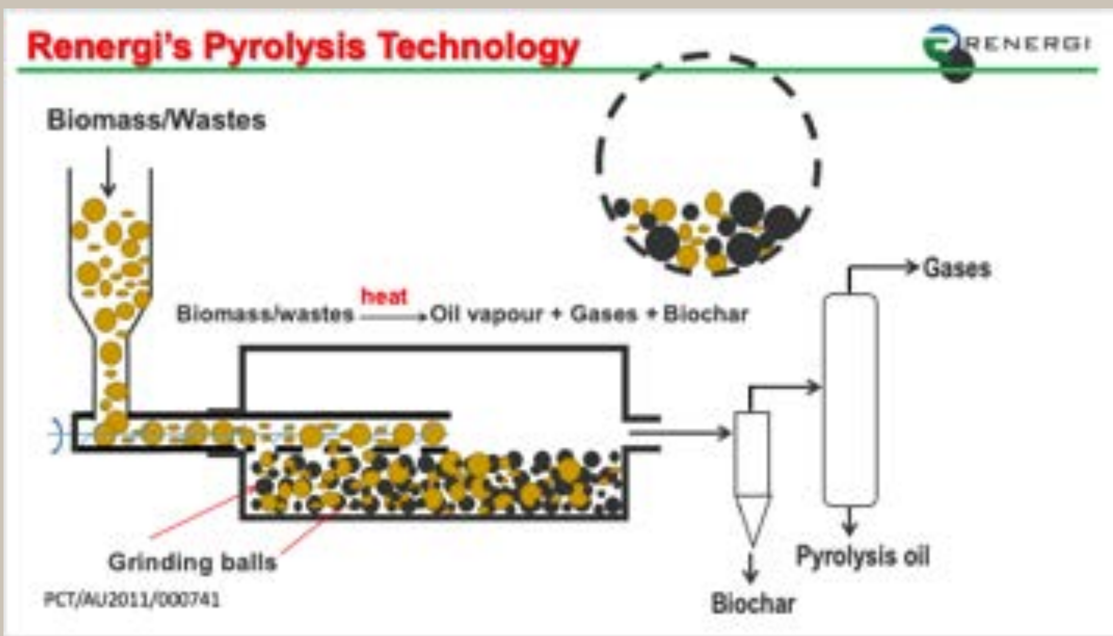
BREZ partner Renergi will use mobile pyrolysis units to process a mixture of municipal and agricultural wastes initially trialling at Emerald for production of biochar and bio-oil.

Biochar is one of the three most economic and commercially available methods of carbon sequestration, attracting a price of over $200 per tonne on the international voluntary market. It has been recognised by the IPCC as one of the lowest cost and scalable methods of carbon drawdown in addition to reafforestation and soil carbon. Char produced from municipal waste has value as an additive to cement or bitumen and other construction materials. Biochar from organic waste can be used as a stockfeed to improve animal performance and a soil supplement to increase land productivity. Fed to ruminant animals it reduces methane output and improves animal output while, after excretion, improves soil fertility and sequesters carbon over much longer periods than known alternatives. It is currently being sold by a Queensland agricultural supplies store into the local market at around $1000 per tonne reflecting local supply constraints.

Bio-oil produced from municipal waste can be used as a fuel for base-load electricity, for refining into transport fuels as a binder and reductant for iron ore, and as a low emissions input to replace coal, oil and gas in other industrial processes.

Emerald Council has a large transfer station where all recyclable material is currently sorted and freighted (at cost) and the balance going to landfill. One Renergi pyrolysis unit with capacity of 12,000 tonnes per year would complete disposal of all combustible municipal solid wastes at Emerald and ameliorate costs for the disposal of secondary wastes and generate up to ten jobs (direct and indirect). Additional environmental benefits of Renergi pyrolysis include reduced air pollutants (CO, NOx, SOx, PM, VOC/Ozone and heavy metals), negative CO2 emissions, and reduction in odour issues.

There is potential for trialling additional units to process waste from fruit and nut products in the Central Highlands irrigation area.



Renewable resources

Underpinning the BREZ model is the provision of competitively priced, sustainable and reliable zero-emission inputs including energy, biomass and water.

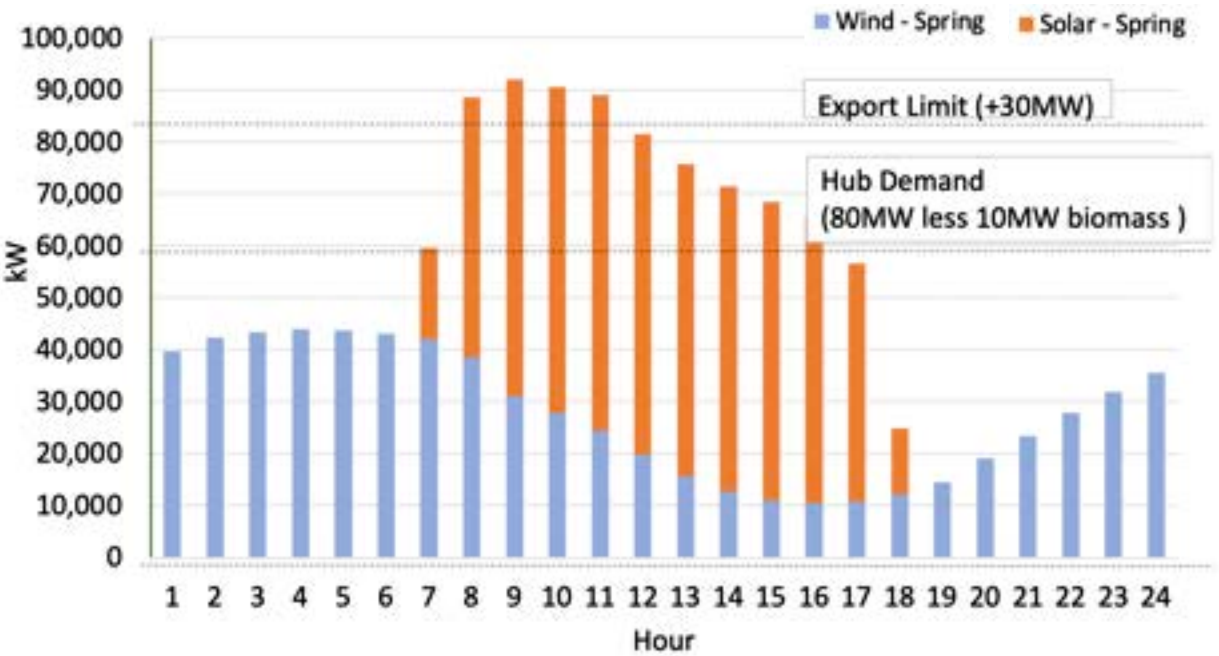
This section summarises relevant attributes of the resource availability in the Barcaldine region.

The renewable energy resources in the Barcaldine region are abundant. The solar resource is the best of all locations connected to the national electricity grid in eastern Australia (Figure 1b) and is outstanding by international standards. The wind resource is good (Figure 1a).

With an existing 132kv transmission line connecting to the NEM via Clermont, Barcaldine is well situated at the nexus of reliable grid connectivity and renewable resource. It is far enough inland to enjoy high insolation (Figure 1b - middle panel) and to avoid the impact of tropical cyclones. Further west of the solar insolation rises but is devoid of grid connection. Locally optimal wind sites occur immediately east of Barcaldine along the west facing slopes of the Great Divide (Figure 1a).

The combination of the extremely high-quality solar resource combined with good quality wind resource facilitates consistent supply as illustrated in Figure 4 which shows the *Spring Average Daily Energy Production*. Importantly, the diurnal energy profile of the wind resource lends itself favourably to complement solar generation. For the BREZ perspective, it means a significant proportion of energy demand can be supplied by blending local wind and solar supply (see further discussion in Section 5).

Figure 4: Spring Average Daily Energy Production



The solar resource

The average area for a 50km radius around Barcaldine has an annual average temperature of 22.8°C and precipitation of 514 mm (for the period of 1986-2015). Positioned at a latitude of 23° south, the optimal tilt angle for a fixed tilt PV plant at this location is 26°, at an azimuth of due north.

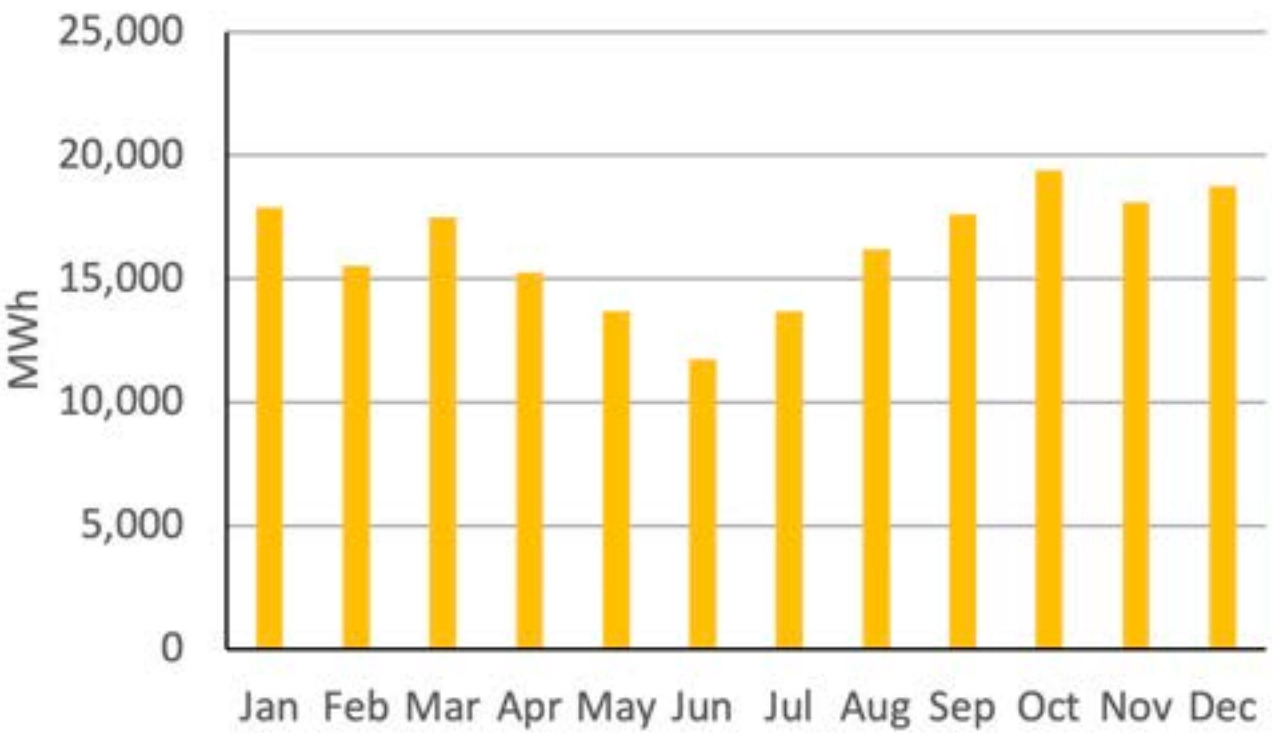
Using BOM data we derive a mean solar irradiation of about 260 W/m^2 for the region of 75 kms radius centred on Barcaldine. The World Bank Global Solar Atlas15 indicates the Direct Normal Irradiation (DNI) at Barcaldine is of 2,622 kWh/m2 p.a. (=299W/m^2). DNI is the 'beam radiation' component of solar resource which is the pertinent measure when considering a single-axis tracked solar farm.

Data obtained from measurements at a ground station in the regional vicinity of Barcaldine calibrated to financing standards and profiled for a single-axis horizontal mounted PV plant re-scaled to a nameplate capacity of 90MWp (Figure 5) yields a headline AC capacity factor of 30.8%

Figure 5 highlights the relatively small seasonal variation especially when compared with southern locations. The annual average monthly energy production is 16,274 MWh, with June at 11,737 MWh (28% lower) and October at 19,394 MWh (19% higher).

The solar farm will be located within the Barcaldine Industrial Hub over the highway from the Ergon switchyard and CCGT power station adjoining the township.

Figure 5: 90MWp solar annual monthly average energy production (ground station, Barcaldine region)



The wind resource

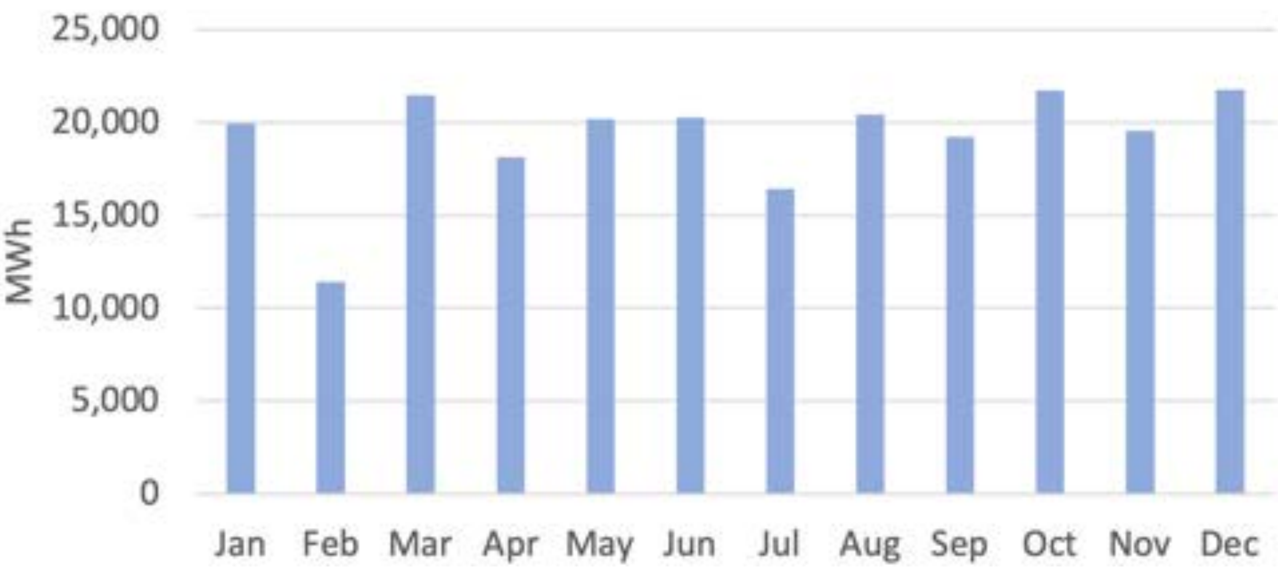
The Sunshot wind site lies 30 km to the east of Barcaldine on a series of NW-running elevated ridges along the western flank of the Great Dividing Range. The area had been prospected for wind in the past. WSP was engaged to perform a virtual mast analysis using wind resource mapping datasets supplied by the Copernicus Climate Change Service. WSP identified the area straddling the Capricorn Highway as having the best local resource in the vicinity of the 132kV transmission line from Clermont. Accordingly, this was adopted as the project location, acknowledging that there will be ample future opportunity to exploit the prospective wind resources further to the north.

The virtual mast analysis points to a moderate quality resource with an annual mean wind speed (AMWS) of 7.4 m/s (14% uncertainty) at 125m hub height. The predominant wind direction is from the SW, or generally orthogonal to the natural disposition of turbine rows, resulting in minimal wake losses.

For the purposes of capacity factor determination, WSP nominated a plant size of 61.6 MW. The estimated Annual Energy Production (AEP) is 237 GWh p.a. with a capacity factor of 43.9% at the connection point (Figure 6). The WSP wind shear estimate points to 7.7 m/s at 150 m hub height.

The WSP Barcaldine Wind Farm 150MW Preliminary Energy Yield Assessment has confirmed commercial grade wind resource sufficient to host a utility scale wind farm of a size needed to meet the electrical load at Barcaldine Hub.

Figure 6: Monthly wind energy production, source WSP Aug 2021, Barcaldine Wind Farm 150MW Preliminary Energy Yield Assessment



Biomass feedstock resources

For Stage 1 of the biomass demand for pyrolysis operations is estimated at about 19,000 tonnes, rising to 145,000 tonnes per annum across Stage 1+2 including Renergi operations (Figure 2).

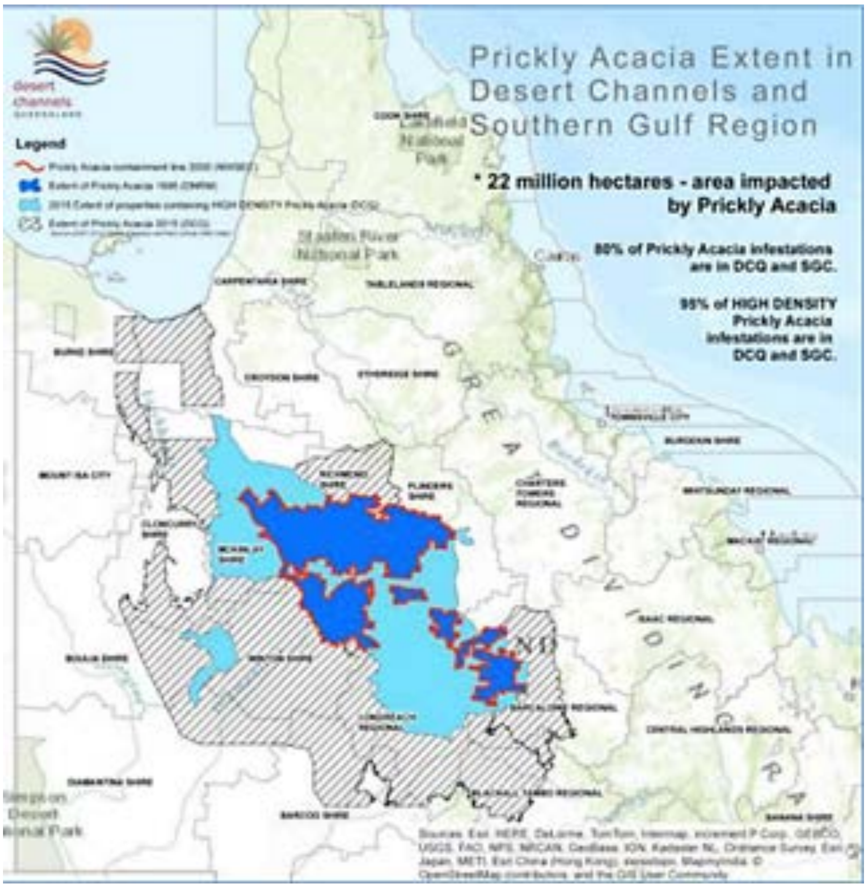
Initially feedstock will be supplied in partnership with environmental management groups responsible for clearing prickly acacia from a 22 million Ha area across Northern and Central Queensland.

Landowner assessments in the 2016 Path to Eradication report, document significant areas of high-density prickly acacia infestations within the 100km to the north of Barcaldine (Figure 7). Sunshot Industries is planning to conduct further assessments of prickly acacia feedstock extending to a 200km radius which involves remote sensing mapping analysis supported by field work. The objective will be to confirm BREZ feedstock longevity over the planned project life of 30 years. Anecdotally there are denser concentrations further afield, especially to the north and northwest, these would be removed at much lower cost and would be accessible commercially to Renergi mobile pyrolysis units.

While using prickly acacia will have added benefit of contributing to its eradication, success will in time necessitate alternative sources of BREZ biomass feedstocks. As prickly acacia supply is exhausted, feedstocks will be provided from productive plantations as outlined in the *Land Carbon Investment Fund Business Model & Plantation Program* section of this report.

Figure 7: Range of prickly acacia across the Desert Channels and Southern Gulf region, sourced from The Road to Eradication, 2016. Desert Channels Queensland

https://dcq.org.au/wp-content/uploads/2016/11/Road-to-Eradication.pdf.

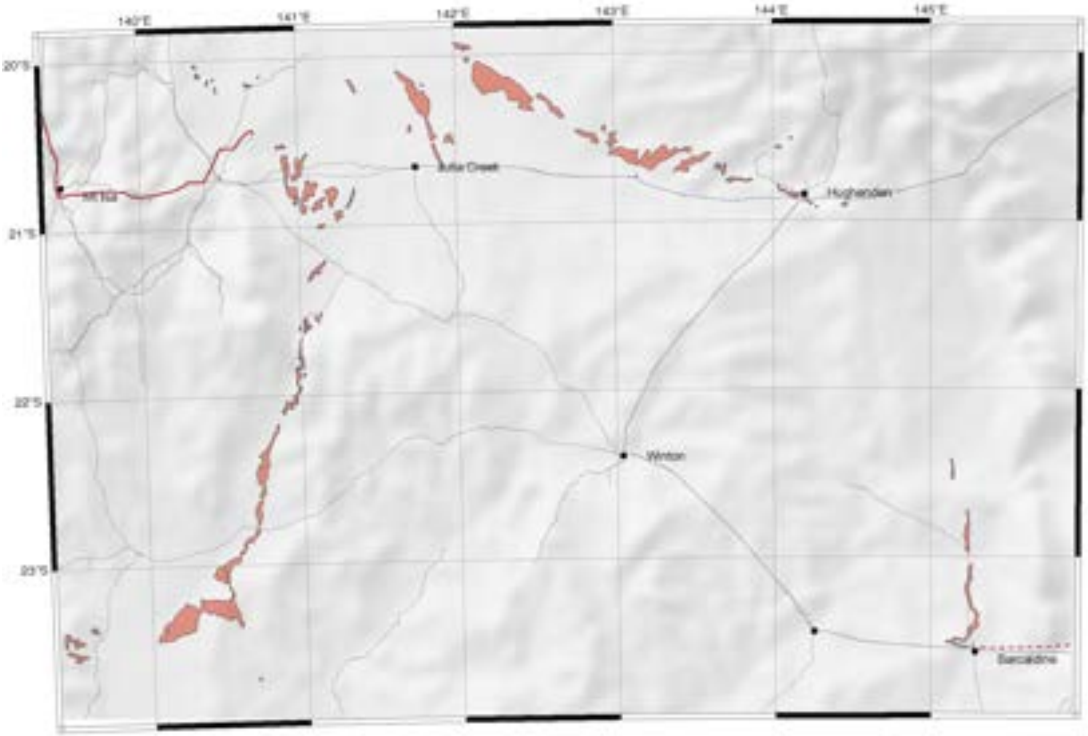


Water and mineral resources

The Barcaldine Post Office (Bureau of Meteorology station number: 36007) has a long-term average (1887-2021) of precipitation of 491 mm (Figure 1, right panel). Located along the north-eastern part of the Great Artesian Basin (GAB) on the Alice River. Water for the Barcaldine Renewable Energy Zone (BREZ) will be sustainably sourced from a number of aquifers within the Great Artesian Basin (GAB). Negotiations are underway to partner with the Queensland Department of Regional Development, Manufacturing and Water (DRDMW) to identify existing free-flowing bores on private land, that Sunshot Industries will rehabilitate to access a proportion of the water for the BREZ. Rehabilitating free flowing bores will save significant quantities of water that are currently being lost from the GAB due to seepage and evaporation from uncapped bores and/or free-flowing bore drains. Partnerships with DRDMW and landholders also prevents the need to drill additional bores into the GAB. This process to source water was chosen as it will have the least chance of a negative impact on the GAB—and possibly a positive effect from capping of old bores-- and the nearby fragile artesian springs and it is anticipated that access to water via this method will be cost-effective.

Barcaldine is located within the Eromanga Basin on local sedimentary bedrock of Mesozoic age. To the northwest, the world renowned Proterozoic-aged Mount Isa mineral province has immense prospectivity for many critical minerals with large undeveloped resources of copper and cobalt. Within the Eromanga Basin, vanadium plays in organic rich shale and limestones of the Toolebuc formation around Julia Creek, are being developed by VECCO to source ore for its proposed BREZ processing plant. With regard to BREZ, it is of note that the Toolebuc formation outcrops along the eastern margin of the Eromanga basin all the way south from Julia Creek to Barcaldine, providing some potential for more local sources of ore.

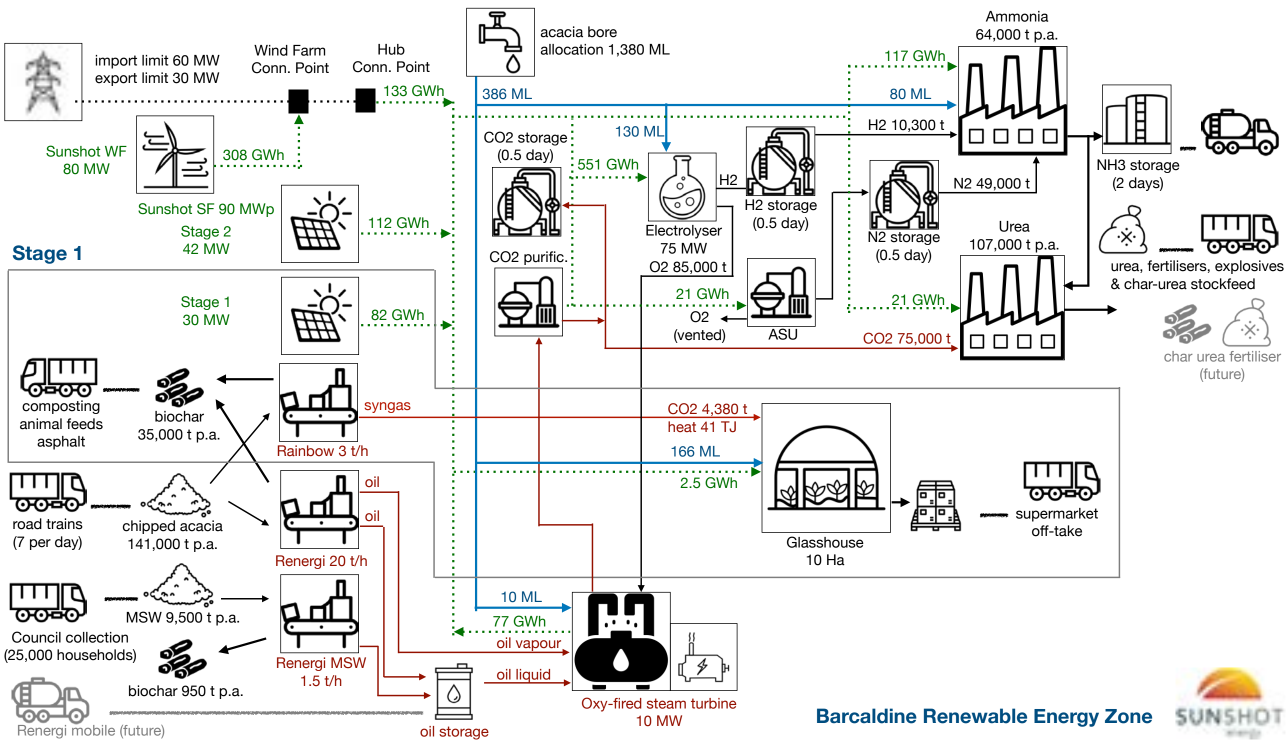
Figure 8: Distribution of the vanadium-prospective Toolebuc Formation (brown) along the north margin of the Eromanga basin, showing distribution. Currently, VECCO plans to source its vanadium supply for the BREZ processing plant from deposits near Julia Creek. The vanadium prospectivity of outcrops in the vicinity of Barcaldine remains to be established.



BREZ market opportunities and supply chain innovation

With its low-cost resource advantages BREZ has significant market opportunities in energy intensive sectors where synergies can be realised, such as in green chemical supply chains.

Figure 9: Integrated supply chain: intensive horticulture, ammonia and urea.



The co-location of production facilities enable by-products and wastes of one process to be provided as low cost inputs for complementary industrial processes. Exploiting such synergies are at the heart of the BREZ concept, and have particular application in relation to use of biomass feedstocks. Examples include in the use of:

- waste oxygen from hydrogen electrolysis as an input for oxy-firing of bio-oil in a steam turbine to produce zero emissions thermal power and carbon dioxide for conversion of ammonia into urea.
- waste heat energy, pure carbon and biochar from pyrolysis units as inputs for co-located intensive horticulture to maintain glass house climates and nutrients for plant growth.
- biomass waste from the production of charcoal and native essences and flavours as a pyrolysis feedstock.

This section documents the market opportunities for the production of green hydrogen, ammonia and urea, and the feasibility of the BREZ providing a good location for production at globally competitive prices.

Urea

Urea is one of the top three globally traded chemicals, with Australia currently importing 92% of its annual ~1.9 million tonnes demand[2]. Conventional urea production uses fossil gas or coal as feedstock. China dominates global coal-urea production, primarily for domestic consumption, but also as a swing exporter. However, with much of the international trade sourced from Middle East fossil gas producers, urea contracts tend to be linked to gas or oil price indices. As is typical of agriculture commodities, the urea market is characterised by high volatility driven by seasonal weather patterns and global shipping demand.

Over the 5 years to 2020, international prices have been in the range of AUD$340-560 per tonne. They were substantially higher in real terms a decade ago. Shipping to Queensland typically added ~AUD$50 to the landed cost, excluding Delivery Duty. Prices in Australia have risen sharply over the past year, reflecting high gas prices, steep rises in freight costs and reluctance to invest globally in new capacity in highly emissions-intensive activities. Some farmers in the central west and southwest of Queensland including through the major demand centres in the Darling Downs have reported difficulties in securing supplies over the past two years, and adjacent regions are reporting paying AUD$900 per tonne delivered for summer crops planted in the Spring of 2021.

Global constraints on expansion of emissions-intensive production from traditional sources are expected to place continuing upward pressure on international prices and to generate continuing concerns about supply chain reliability. As China attempts to reduce gas and coal use in domestic manufacturing to meet climate change objectives, it is expected to reduce urea exports. The incentives for increasing local Australian production are manifest.

For these reasons, local urea production targeting a benchmark price less than AUD$500 per tonne at point of production is seen as globally competitive. There are advantages in this being achieved with zero emissions. Local production would clearly increase domestic supply security. In addition to an inherent freight cost advantage, domestic supply de-linked from gas input prices and the vagaries of international shipping, would reduce exposure of Australian farmers to highly volatile commodity price fluctuations and security concerns. It is an economically rational aspiration for Australia to shift from being a large net importer of urea to a net exporter over the next one or two decades. This would see the basis of pricing to domestic farmers shifting from import parity (international (mainly Middle East) prices plus freight) to export parity (international prices less freight)—potentially a downward swing of $100 per tonne to local farmers at current international freight rates.

[2] https://fertilizer.org.au/Fertilizer-Industry/Australian-Fertilizer-Market

Within the greater Barcaldine region, urea has high value in the cattle feed market, where it is used in high-protein molasses-rich supplements. This is a natural first market. A second local market is the Central Highlands nitrogenous fertiliser market[3].

Conventional urea production from coal and gas, as at the Incitec Pivot Plant in Brisbane and in all of the international suppliers to Australia, is one of the most emissions-intensive industrial processes. It therefore exposes the dependant agriculture sectors to significant carbon penalties (see Break Out - Carbon Penalties). Most emissions arise in the production of hydrogen from steam reformation of fossil hydrocarbons. These emissions are removed by making hydrogen from electrolysis using renewable energy. There are also emissions in the carbon dioxide used to convert ammonia (made from hydrogen) into urea. These will be removed in Barcaldine by using carbon dioxide from combustion of bio-oil in a steam turbine for power generation using oxygen waste from the production of hydrogen through electrolysis. The BREZ will host Australia's and probably the world's first commercial production of zero net emissions urea[4], both in the production of ammonia, and its conversion to urea, using biogenic carbon dioxide. In contributing to decarbonisation of what has been one of the most carbon-intensive elements of the agricultural supply chain, this will provide competitive advantage for Australian farmers in high value Australian and international markets seeking low-emissions sources of agricultural products. It will provide Australian farms with protection against future restrictions on emissions-intensive imports, and be a positive differentiator and source of a premium for low carbon produce.

REDUCING EXPOSURE TO CARBON PENALTIES

As national and international carbon compliance schemes develop, penalties will apply to products from high-emissions supply chains. Carbon border taxes or more arbitrary restrictions on imports from high-emissions sources are likely to be applied in important Australian markets for farm products. Products with certified low- or zero-emissions supply chains will have advantages in market access.

Beyond carbon penalties implemented by our trading partners or Australia's national policy, private carbon markets are being driven by multinationals such as Microsoft, Kellogg's, Proctor and Gamble and McDonalds fast food company which are implementing net zero targets across their supply chains. Due to shareholder and consumer pressure corporate targets are aggressive, with the net zero by 2030 a common goal.

[3] Preliminary wider market analysis of the Queensland market, has been undertaken in respect of import substitution price benchmarks in different region. In respect of volume, in June 2021 agriculture consultants RMCG were engaged to characterise the Queensland fertiliser market in terms of size, customer segments, distribution, buying behaviour, existing producers and import volumes.

[4] Note that low-emissions urea will be similar to high-emissions urea in its contribution to some greenhouse gases such as nitrous oxide. However being much lower net emissions in production, BREZ urea will require lower levels of offset purchases or on-farm sequestration to achieve a net zero carbon supply chain.

Green Ammonia and Hydrogen technology development

There is growing international interest in renewable ammonia derived from green hydrogen in the fertiliser and chemicals markets and as a hydrogen carrier for energy exports. A priority for BREZ is de-centralised green ammonia production for agricultural uses such as fertilisers, urea and char-urea stockfeed. There is an opportunity for expansion to supply ammomium nitrate for explosives for the mining sector.

Historically, hydrocarbon-fed ammonia plants have relied on steam methane reforming (SMR) to provide the hydrogen and tend to be co-located within industrial hubs where heat, electricity and product streams are integrated across the complex. In recent years there has been much interest in green ammonia pilot projects globally and in Australia, with all Tier 1 technology licensors (Haldor Topsoe, KBR, Casale and Thyssenkrupp) now[5] developing designs to integrate renewable powered electrolysers.

Continuous improvement in the cost and performance of hydrogen electrolysis has accelerated markedly over the past 5 years with realisation of hydrogen's potential pivotal role in the transformation of stationary energy and transport. The technology has matured sufficiently to shift the emphasis toward market activation, building supply chain competitiveness and bankable assets. As a primary determinant of green ammonia production competitiveness, the cost of hydrogen is critical. The CSIRO Hydrogen Roadmap[6] anticipates hydrogen costs falling to $2.29-$2.79/kg by 2025, when industrial feedstock, such as ammonia, are expected to become competitive at these hydrogen prices.

Currently, the three main hydrogen electrolyser technologies in contention[7] are alkaline, proton exchange membrane (PEM) and solid oxide (Figure 10). Alkaline is the most widely deployed commercially and has the dominant share of the market. PEM is currently more expensive but has greater potential for cost reduction. PEM is more responsive and is likely a better fit when power supply is variable. Solid oxide electrolysers promise a step change in performance but are less mature.

A global supply chain shift to China is occurring. European OEMs are beginning to manufacture in China in their own right or entering into technology licensing partnerships (e.g. Suzhou Cockerill Jingli). Chinese electrolysers are well established internationally (e.g. Peric 718 and Tianjin), with others more domestically focused (e.g. Beijing CEI, Sungrow).

5 Trevor Brown Consulting: https://ammoniaindustry.com/all-together-now-every-major-ammonia-technology-licensor-is-working-on-renewable-ammonia/, 31 May 2018

6 CSIRO 2018, National Hydrogen Roadmap: Pathways to an economically sustainable hydrogen industry in Australia

7 KBR Sept 2020: Barcaldine Green Ammonia and Urea High-level Concept Study

Figure 10: Electrolyser Technologies Efficiency-Cost Comparison (courtesy KBR)

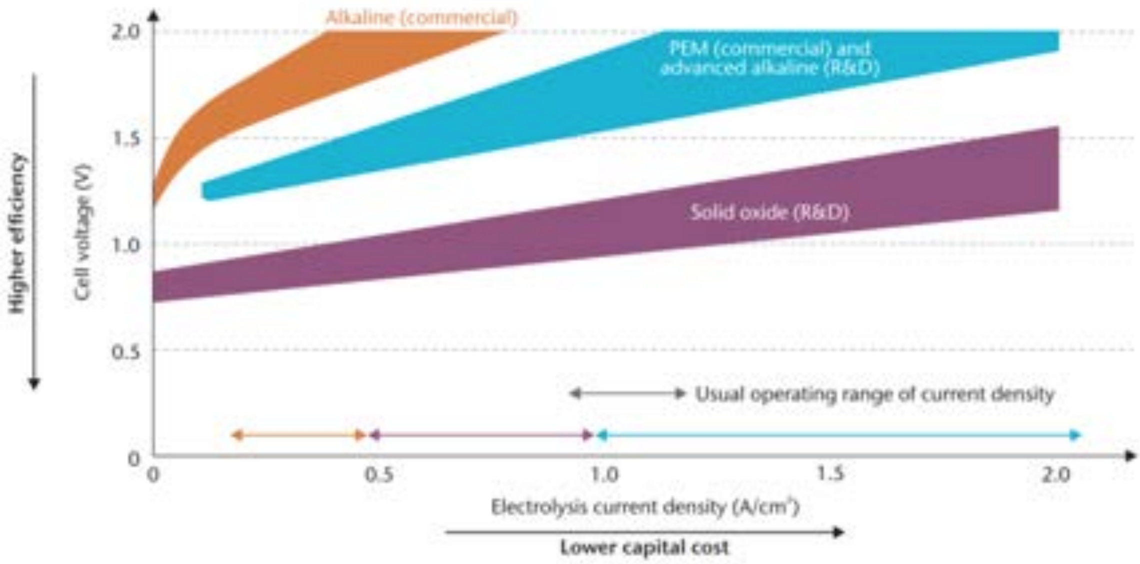
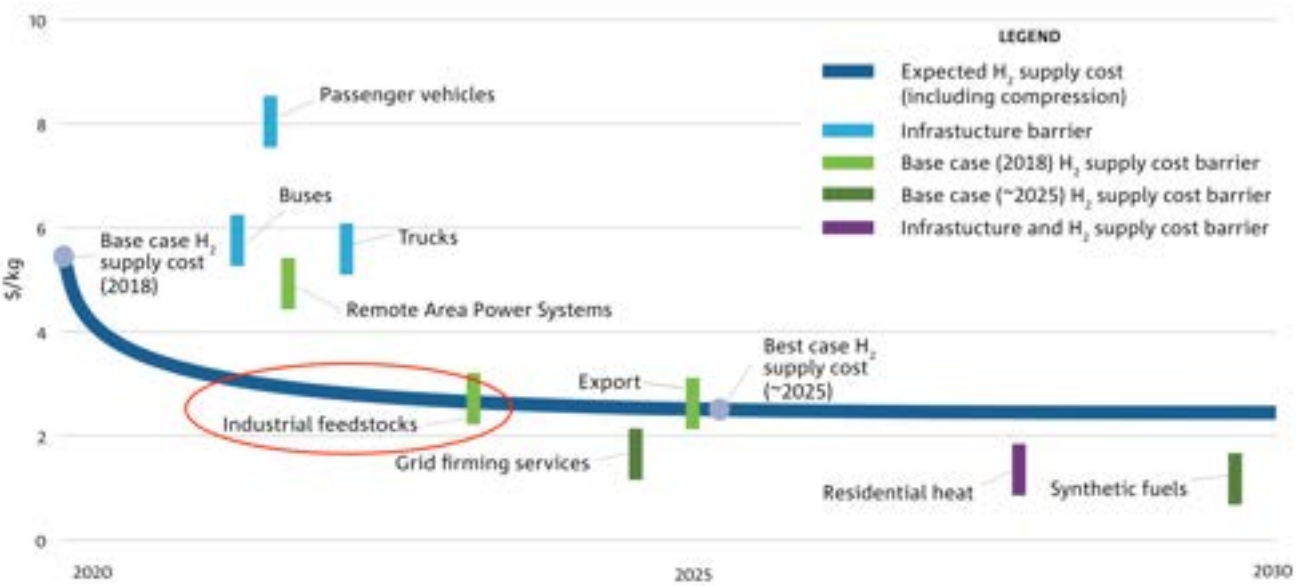


Table 1: Major Electrolyser Suppliers (Institute for Energy Economics and Financial Analysis: Great Expectations Asia, Australia and Europe Leading Emerging Green Hydrogen Economy but Project Delays Likely. Yong-Liang Por, August 2020)

		2020		Previous FY		Notes
		PEM	Alkaline	Revenue	NP	
	BBG	MW	MW	US$mn	US$mn	
Hydrogenics	CMI US	undisc.	undisc.	34	-13	Acquired by Cummins in 2019
Nel Hydrogen	NEL NO	40	360	63	-30	Acquired Proton Onsite (US PEM producer) in 2017
ITM Power	ITM LN	350	-	6	-12	Supplying 10MW PEM for Shell in Germany
McPhy Hydrogen	MCPHY FP	undisc.	undisc.	13	-7	Integrated hydrogen infrastructure provider
Asahi Kasei	3407 JP	-	undisc.	19,789	956	Supplied 10MW alkaline electrolyser for FH2R project
Thyssenkrup	TKA GR	-	1000	48,300	-299	Scaled up manufacturing capacity to GW scale
Siemens	SIE GR	undisc.	-	99,876	6,440	Implemented PEMs in Germany of 3-6MW
Tianjin Hydrogen Equip.	Not listed	-	undisc.	undisc.	undisc.	Global leading supplier of alkaline electrolysers
Beijing CEI Technology	Not listed	undisc.	undisc.	undisc.	undisc.	Key player in China PEM market

Sources: Companies, IEEFA estimates.

Figure 11: Hydrogen competitiveness in targeted applications (CSIRO 2018, National Hydrogen Roadmap)



The estimated BREZ green ammonia plant capacity of 60,000 tonnes p.a. is an order of magnitude smaller than world-leading production plants. The BREZ plant must also differ from leading off-the-shelf designs in being all-electric due to the absence of sufficient waste heat from elsewhere in the hub. For these reasons the BREZ ammonia plant requires a novel design as schematic illustrated in Figure 12.

The base case of 60,000 t p.a. requires 689 GWh p.a. to power the electrolysers and ammonia plant, representing 97% of BREZ electricity load, and 220 ML of water sourced from local geothermal bores (Figure 12). The electrolyser is rated at 75 MW.

While maintaining high asset utilisation is a normal objective for favourable project economics, in de-centralised hub powered from intermittent renewables, there is a trade-off to match renewable resource availability with loads run at full production 24/7, as discussed in the energy optimisation section.

Electrolysers are the ideal 'swing item' because they are by far the largest load at the hub and can tolerate operating at capacity factors of 60% with only a 13% increase in hydrogen cost.

The analysis that follows for hydrogen, ammonia and urea relies on a separate study performed by KBR in Singapore to review electrolyser equipment and process designs suited for the smaller scale of de-centralised, all electric ammonia production, and to derive high-level costings. These are based on European technology licensing which forms the financeability benchmark from which supply alternatives can be assessed. The KBR costs are brought into this study in context of hub energy supply optimisation and to provide a preliminary view of green ammonia and urea economic prospectivity under uniform hub financing assumptions.

Financial Analysis

The analysis that follows summarises a review undertaken by KBR of electrolyser equipment and process designs suited for the BREZ requirements of small scale, de-centralised, all electric ammonia production. The costings, which are based on European technology licensing, serve as a benchmark to inform economic viability.

The project has potential to align to the Northern Australia Infrastructure Fund (NAIF). Accordingly, indicative assumptions of a NAIF funding package have been incorporated in this concept study and will be verified in subsequent stages of development. The financial analysis assumes a 30-year project life, gearing of 80% and debt of 1% real ($2020).

Hydrogen electrolysers produce both hydrogen and oxygen in mass ratio of 1:8, with the hydrogen the main product for ammonia production. The BREZ process will use the oxygen stream, which would otherwise be surplus, for oxy-fired combustion of bio-oil in a steam turbine to produce a net-zero CO2 rich flue gas from which, in turn, is captured, purified and compressed into a urea feedstock.

The KBR analysis that estimates a levelised cost of hydrogen (LCoH) under favourable capital arrangements shows hydrogen costs in line with CSIRO Hydrogen roadmap forecasts by 2025.

In effect, the availability of high-quality renewable resources at Barcaldine, including the otherwise wasted oxygen streams, together with NAIF funding, brings forward CSIRO's projection by 4 years. The attractive hydrogen input cost supports the prospect for establishing globally competitive ammonia production at Barcaldine.

The ammonia plant nameplate capacity of 60,000 t p.a. is matched to urea production with slight over-sizing built in for production buffering. It enables urea to run at full capacity while the ammonia storage tank (2 days) is built up, typically to manage production interruptions and during start-up and shutdown.

Cost Reduction Pathways

The three main levers to pull to achieve a competitive cost position are: equipment capex, electricity input costs and monetising carbon drawdown in environmental markets.

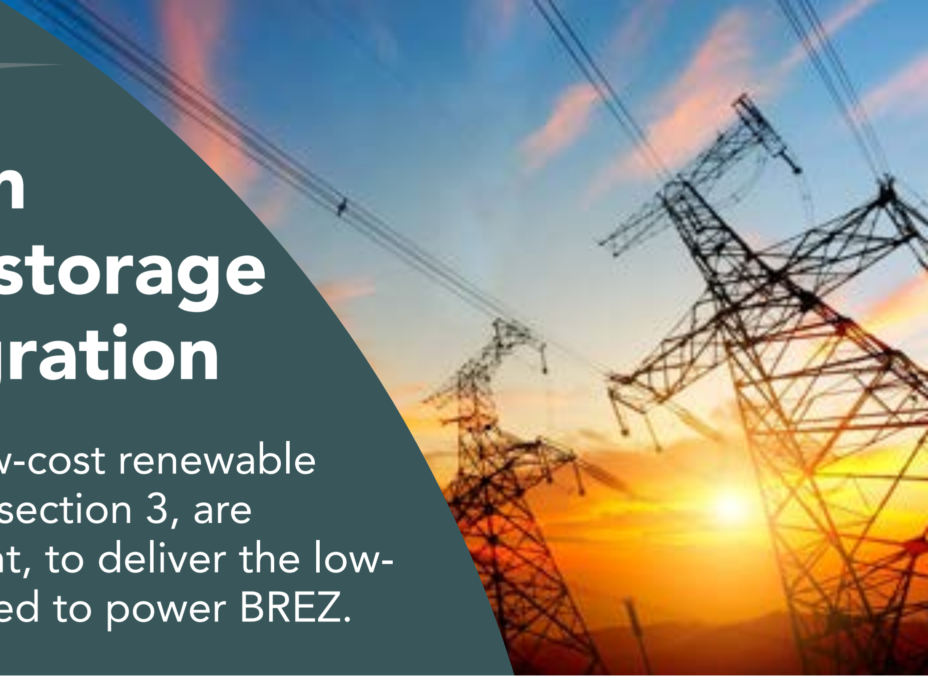
In August 2021, Sunshot engaged with Shanghai Electric Corporation (SEC) to assess their electrolyser technology credentials, contracting approach and company capability. The SEC report provided pre-feasibility confirmation of vendor and EPC contractor offerings, and a pathway to cost reductions while maintaining a set of financeable contracting arrangements. In regard to technology access, in August 2021 Sunshot engaged with SEC to request a concept design suitable for oxy-firing pyrolysis oil coupled to steam power generation.

SEC brings a track record of involvement in oxy-firing pilot and demonstration projects in Australia. The SEC preliminary work validates the choice of oxy-firing.

Following the successful footsteps of Rainbow obtaining biochar PURO certification, the Renergi biochar has a high likelihood of doing likewise. Case A includes Renergi biochar accreditation at \$50 /t CO2e (PURO currently trades upwards of \$100 /t) and bio-oil ERF[8] accreditation at \$15 /t CO2e (ERF currently trades at a bit over \$20 per tonne). Taken together, and using NAIF debt funding, the hub can plausibly deliver a levelised cost of urea (LCoU) at globally competitive prices.

[8] Commonwealth Government Emission Reduction Fund

Energy system optimisation, storage and grid integration



Access to the excellent low-cost renewable resources, as described in section 3, are necessary, but not sufficient, to deliver the low-cost reliable energy required to power BREZ.

To provide both competitive electricity prices and a reliable supply of hydrogen, additional balancing resources are required. The existing 132kv transmission connection to the eastern seaboard grid provides one low cost balancing option, allowing imports when local renewable energy output is low as well as export revenue when conditions allow. Storage technologies provide a further balancing option.

This section reports an analysis to determine if optimisation of the combinations of renewable resources, combined with existing grid infrastructure and storage technologies can further reduce costs. It includes an overview of the optimisation assumptions and approach; the characteristics of electricity market supply and details of the network connection limits and a summary of results in term of optimal mixes of generation, storage and hub configuration.

Optimisation approach

BREZ Stage 2 is sized to deliver 60,000 tonnes p.a. of green ammonia[9]. Ammonia production is a continuous operation, requiring a consistent feed of both energy and hydrogen, providing a target constraint for optimisation.

We explored three main strategies to a low cost and consistent feed of hydrogen. A base strategy didn't consider storage at all. In this case, all balancing requirements were assumed obtained directly from the grid. A second case involved balancing with local battery storage of electricity along with the grid, and the third case involved additional storage of hydrogen.

The base case strategy relies on a combination of imports from the grid and local renewable energy production to ensure the electrolysis unit produces a consistent supply of hydrogen, at a high utilisation rate. The case with electricity storage similarly ensures a high utilisation rate of the electrolysis unit, but with battery storage able to store excess renewable energy and/or grid imports. The hydrogen storage strategy relies on a buffer of hydrogen, post electrolysis. In this case, flexible operation of the electrolysis units results in higher utilisation of low-cost energy from local renewable resources or the grid, at the cost of lower utilisation of the electrolysis unit.

These strategies were optimised in combination with electricity supply options and grid constraints to deliver lowest cost and reliable supplies of hydrogen and electricity to the hub. The sources of electricity considered include wind, solar and imports from the national electricity market.

[9] This sized was initially informed by the grid connection capacity available at Barcaldine.

Imports from the National Electricity Market

The National Electricity Market (NEM) provides a natural and low marginal cost option for balancing the needs of the hub with the local production of renewable energy. Additionally, the evolving profile of electricity prices in the NEM provides potential arbitrage opportunities for the BREZ energy suppliers. As discussed further in the next section, this could be direct electricity arbitrage via battery energy storage, or arbitrage through shifting consumption of electricity to utilise low-cost electricity. Figure 15 shows the profile of electricity prices in Queensland market region in the previous 12 months.

For the purposes of the optimisation, we use electricity market data that was aligned with the solar and wind mast data provided by WSP, as described in the previous section. This was done to ensure temporal linkage between weather patterns and electricity price dynamics were maintained.

Barcaldine is currently connected to the NEM by a 132KV line via Clermont. The line has nominal capacity of 80MVA, with seasonal variation as outlined in Table 4. The current flows by time of day are illustrated in Figure 16. The overnight load is approximately 10MW, peaking at 21MW between 7-10pm and existing solar generation of 42MW (57MWp) results in daytime net export of 30MW. Based on the network analysis provided by Ergon, during the day we have assumed a 30MW export limit and a 60MW import limit on the 132kV line.

Figure 15: Wholesale electricity prices, by time of day, in Queensland over the past 12 months

Figure 16: Total load on Clermont-Barcaldine 132kV feeder by time of day

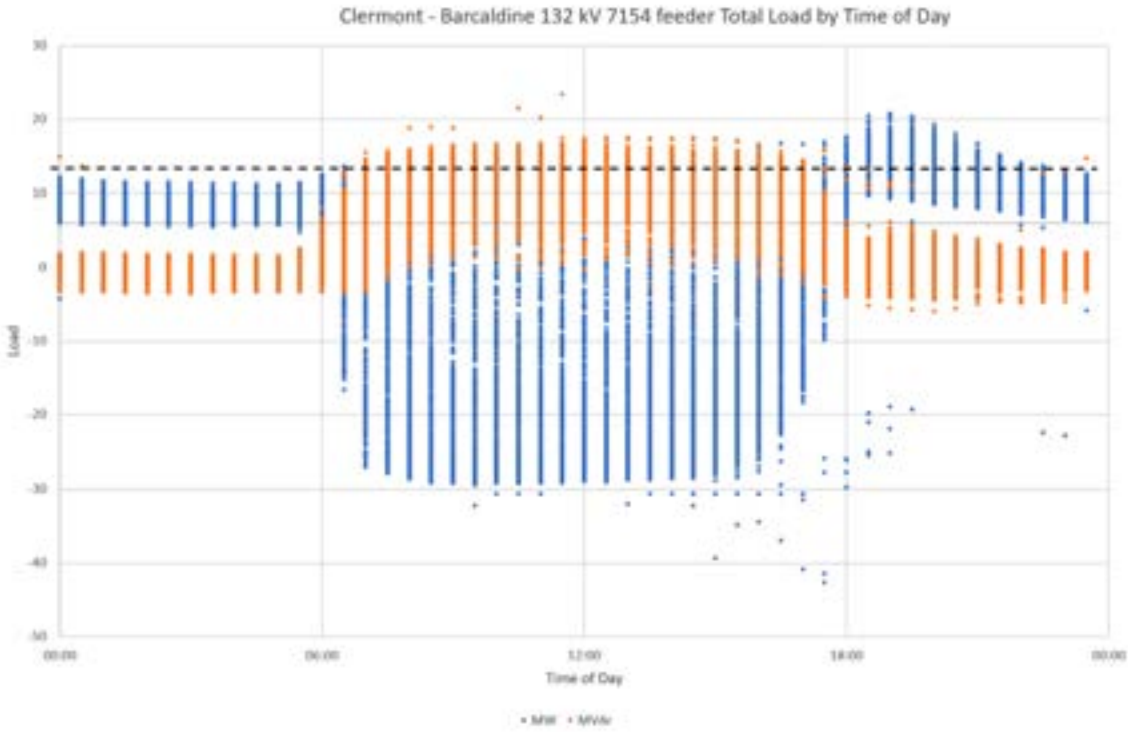


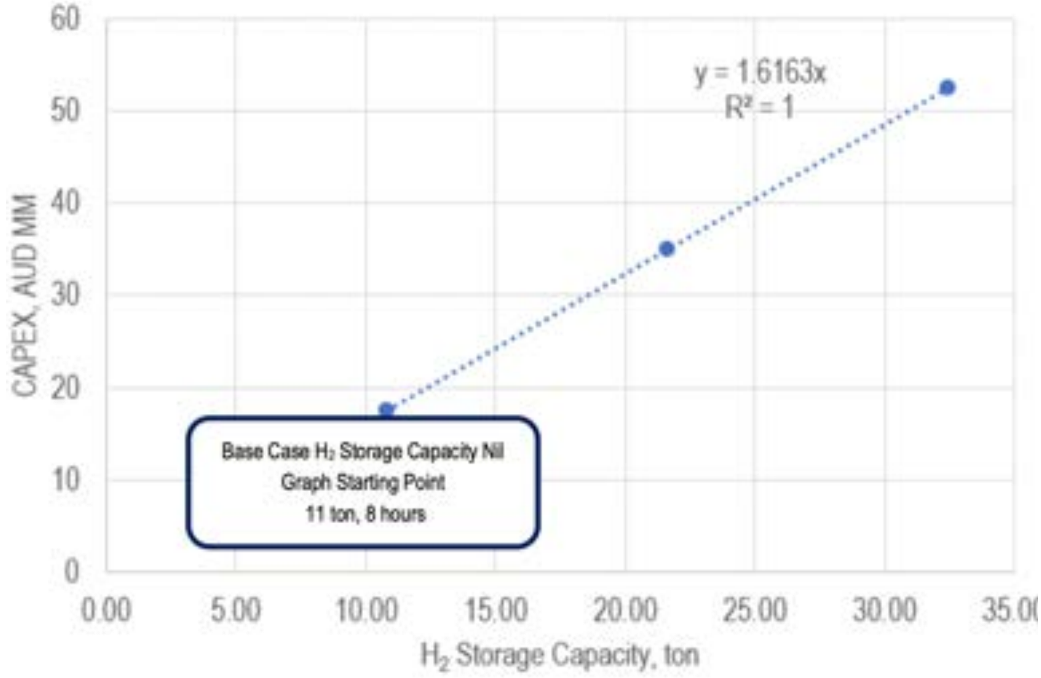
Table 4: Line capacity of Clermont - Barcaldine 132kV feeder

	Morning	Day	Evening
Summer	72.2	74.1	80.5
Winter	80.2	79	84

Storage technologies

Battery storage and hydrogen storage were both considered as options to maximise renewable utilisation and electricity arbitrage opportunities. We used battery storage costs based on CSIRO's GenCost 2020 report, and hydrogen storage from KBR consulting.

Figure 17: Hydrogen storage cost (provided by KBR)



Optimisation analysis

The electricity price profile, grid constraints and storage costs were combined with the renewable energy resources described in the previous section to determine the optimal mix.

The optimal solution configuration suggests an over build of wind (with some imports) is preferable to large amounts of self-generation of solar electricity. In addition, the analysis suggest that the cheapest solution utilises a slightly oversized electrolyser and hydrogen storage, rather than battery storage. Table 5 shows the optimal configurations for the three main strategies analysed.

This relatively high penetration wind is somewhat unsurprising given Queensland's electricity market price profile characterised by very low midday prices (Figure 15). The overbuild of wind and utilisation of low-cost grid imports results reduces the size of solar installation. Of note is that the optimal wind capacity is approximately two times the transfer limit of the 132KV line. This is because at maximum capacity the wind farm can simultaneously transfer 60MW eastwards towards the NEM and westwards toward the BREZ.

The hydrogen storage strategy resulted in the greatest cost savings. The relatively long duration of storage enables greater utilisation of both low-cost grid electricity in solar hours and self-generation of solar than is economically possible with battery technologies at current prices. Battery technology costs are well suited to covering evening and morning peaks, but less well suited to the bulk shifting of hours of low-cost solar energy compared with hydrogen storage.

Figure 18 shows the average yearly supply and storage profile for the optimised case, by time of the day. As illustrated, BREZ tends to import low-cost electricity during the day, and export some higher value wind outside daylight. The storage of hydrogen tends to build up during the day, and draw down during the evening peak, when grid supply is more expensive. As can be seen, it is likely to be more economic to export wind generation and draw down hydrogen storage, rather than directly consume the power to produce hydrogen.

To highlight the importance of grid connection and storage operation Figure 19 shows a low wind week, while Figure 20 shows a windy week.

Figure 18: Hub supply and storage profiles. The top panel shows the average supply profile by time of day over the period analysed. Areas below zero indicate export to the National Electricity Market. The bottom panel shows the average profile for hydrogen storage.

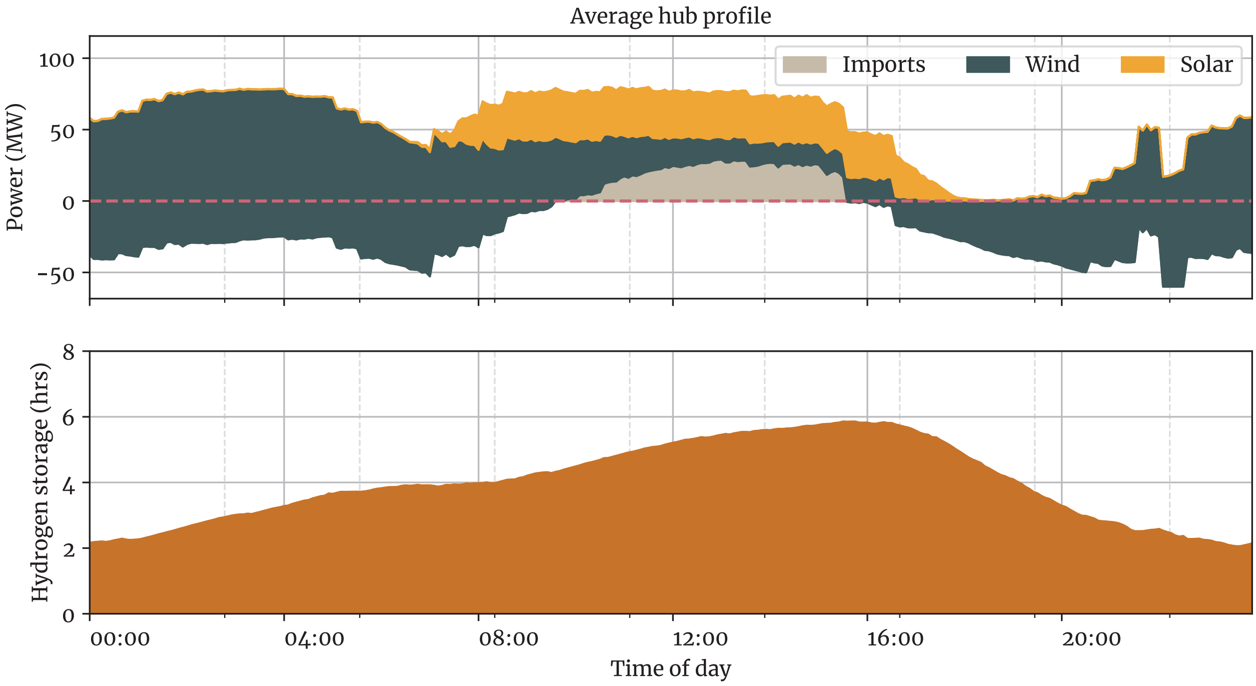


Figure 19: Hub supply and storage profiles during low renewable availability. The top panel shows the average supply profile by time of day for a week with low wind. Areas below zero indicate export to the National Electricity Market. The bottom panel shows the average profile for hydrogen storage over the same period.

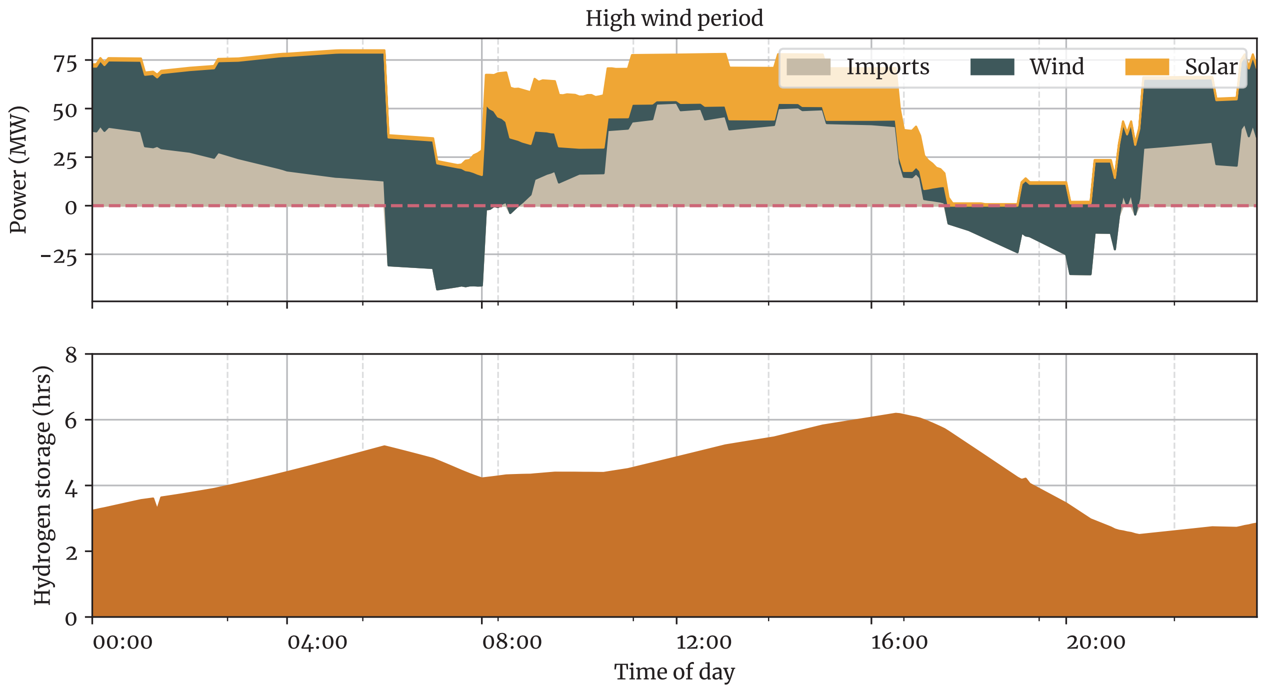
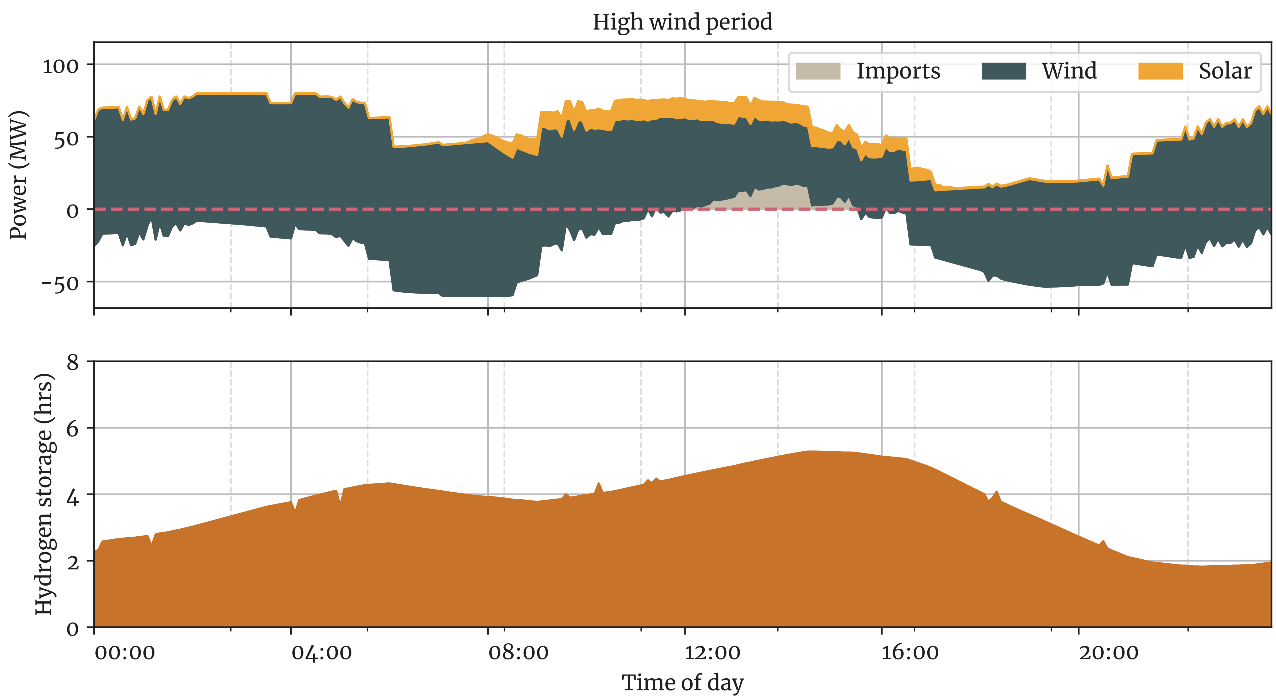


Figure 20: Hub supply and storage profiles during high renewable availability. The top panel shows the average supply profile by time of day for a week with high wind. Areas below zero indicate export to the National Electricity Market. The bottom panel shows the average profile for hydrogen storage over the same period.



During windy periods the value of export capability of the transmission is maximised, while storage is utilised to some extent to exploit energy market arbitrage opportunities.

The optimisation results are sensitive to the electricity price modelled, wind trace and network capacity, as well as input assumptions such as electrolyser and hydrogen storage costs. Any costs changes in battery storage relative to electrolyser and/or hydrogen storage costs will necessarily change the balance. Changes to assumptions of cost of capital tend to change the amount of storage built as reflected in hours of storage, rather than the capacity as reflected in dispatch rate in MW.

Different assumptions on the value of self-production of solar energy will also yield different optimisations. For example, any perceived benefit in reducing exposure to spot price volatility through self-generation would warrant higher installed solar capacity. Given the current price dynamics and expectations of further solar installations on the NEM (including in the residential solar market) the grid-value of solar generation is likely to further diminish over the near term.

Fit for Purpose Electricity Transmission

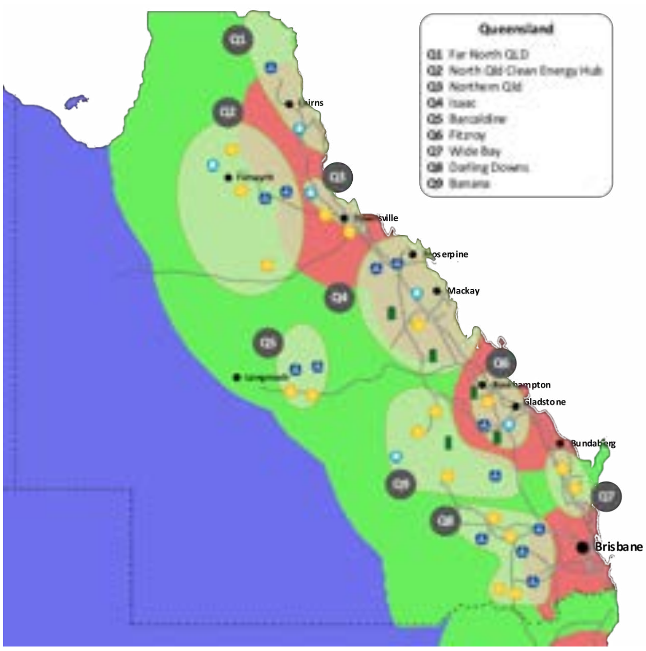
Enabling infrastructure such as transmission and energy storage needs to be developed to realise Queensland's opportunity to accelerate rural and provincial development in the zero carbon world economy. Nine renewable energy zones (REZ) have been identified in Queensland in the optimal development pathway. Barcaldine is one of them.

While there is immense potential for renewable energy generation, the current transmission hosting capacity is a severe limiting factor on its use. This is a particular issue for the six identified REZs in North Queensland, where the existing transmission can support less than 6% of the potential identified generation.

AEMO's least cost development pathway suggests 2 GW of additional utility stage energy storage will be required in Queensland in the next decade (and more than 4.5 GW out to 2040). This makes no allowance for utilising Queensland's large opportunities to supply zero emissions processed minerals and other products including hydrogen derivatives into world markets. Currently only 350 MW is committed, including the 250 MW Kidston pumped hydro project. Several other storage proposals are at very preliminary stages of development including the 1000 MW Borumba Dam pumped hydro project. Arbitrage opportunities in the Queensland electricity market indicate storage is already economically viable, and its further development will both help support renewable energy developments and ensure Queensland electricity prices remain competitive. Electrolysers to produce zero emissions hydrogen contribute positively to power security and reliability with large-scale use of renewable energy for industry if regulatory arrangements are designed to recognise their value.

Resolving the transmission and storage constraints and associated energy cost disadvantage will enable the Precinct model to deliver on the key priorities of the Palaszczuk Government's Unite and Recovery Strategies, including "Making it in Queensland", "Attracting manufacturers to Queensland", "Powering regional development" and "Growing our regions [by] helping Queensland's regions grow by attracting people, talent and investment, and driving sustainable economic prosperity". It also will contribute to the Palaszczuk Government's ambitions: "Queensland has the potential to become a renewable energy superpower", develop Renewable Energy Zones and achieve its target to achieve 50 per cent renewable energy by 2030 and for zero-net carbon emissions by 2050. These priorities have been reinforced by the Palaszczuk Government's Draft State Infrastructure Strategy. The Hub also delivers of the Palaszczuk Government's Queensland Jobs Fund priorities, including the focus of the Industry Partnership Program for "Proposals which create growth and jobs in regions will be a priority".

Figure 21: Proposed Renewable Energy Zones in Queensland. The red and green areas represent regions with low and medium connection costs.

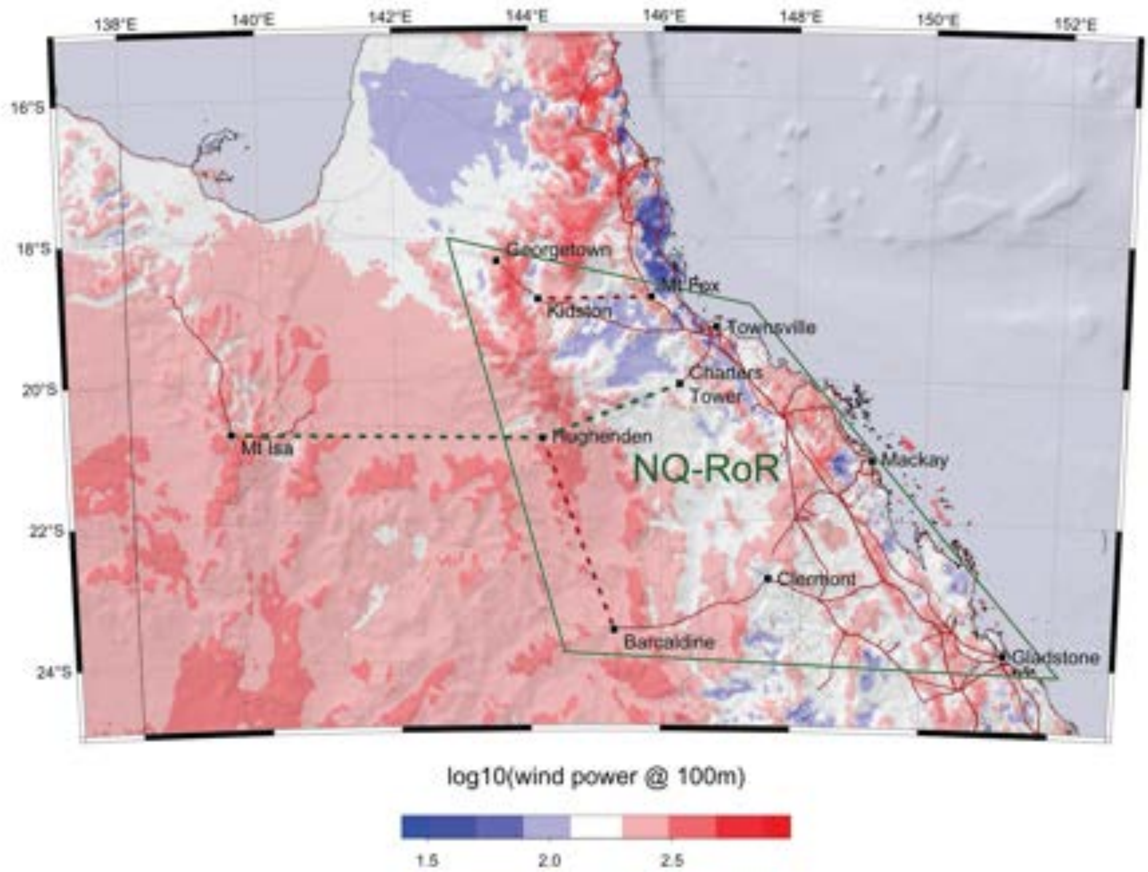


For Barcaldine, the first essential transmission requirement is to ensure that the 132kv line to Clermont performs as required for the renewable energy zone. There will need to be a connection to the line about 30km east of Barcaldine to take in wind power for transmission back to Barcaldine and on to Clermont. There will also be work in connecting the industrial precinct with the Ergon network centre across the highway. Timeliness and cost of these connections will be important to smooth development of the BREZ. Both would be assisted by inclusion in the Queensland renewable energy zone funding priorities.

There would be high State value in upgrading the transmission line east from Barcaldine. This would serve the larger purpose of supporting the emergence of Gladstone as a major base for zero emissions energy-intensive industry—providing access to large quantities of globally competitive solar and wind. A double 330kv line similar to that envisaged in the CopperString project between Mt Isa and Townsville would underwrite substantial development in the central highlands and at Gladstone, and incidentally allow a wider range of energy-intensive development at Barcaldine and adjacent places.

High State value would come from a big third step: joining Barcaldine to the CopperString line at Hughenden. This would greatly expand the capacity and value of the CopperString connection of the wind resources of Hughenden and solar resources of the west to Townsville by providing redundancy. It would complete what Sunshot Zero Carbon Futures and the WWF have described as a "Rhombus of Reliability", with Gladstone, Townsville, Hughenden and Barcaldine at its corners. This would link the abundant and rich solar and wind resources of the near west of central and north Queensland, the immense hydro-electric and pumped hydro-electric storage potential of the Great Dividing Range in central and north Queensland, the industrial cities of the coast and the established economic infrastructure initially built for coal through the Great Divide in the latitudes between Gladstone and Townsville. This would set up the large area along and within the Rhombus for low-emissions industrial development as the world moves towards zero net emissions.

Figure 22: Wind resource and transmission in the Rhombus of Reliability (NQ-RoR), Existing transmission in solid red lines. Proposed transmission extensions include the CopperString 2.0 (dashed green) and the Barcaldine-Hughenden and Kidston-Mt. Fox (dashed red) lines as submitted in the WWF briefing note to the Queensland Government 'Options to accelerate decarbonisation in Queensland'.



Land Carbon & Productive Plantation Business Model

Australia is well endowed with land for absorbing carbon and growing biomass.

Australian high rainfall area forests are known to contain some of the densest landscape carbon stocks in the world. There are also significant opportunities to store carbon in our semi-arid landscapes. Large areas of sparse vegetation can add up to significant quantities of carbon and some of the Australian natural heritage is unusually well suited to efficient growth of biomass in the dry environments that are predominant in inland Queensland.

Storing carbon in landscapes while co-producing commercially valuable oils, seeds or fruits and biomass for industry provides for a land use model that augments established agricultural and pastoral purposes with diversified additional revenue streams. Similarly, as a soil amendment, biochar can improve land productivity. Such 'value stacking' of revenue streams can improve long-term profitability of land-use systems by increasing resilience to changing climates. Re-afforestation of shelter belts and wind breaks has co-benefits such as improved soil health and water retention with concomitant increase in agricultural productivity.

Provision of biomass for BREZ beyond the initial stage of harvesting of prickly acacia infestations will require new dedicated feedstock crops. Understanding how to optimise sustainable biomass feedstock cropping requires a broader view of the opportunity for agricultural landscape carbon in the semi-arid regions in inland Queensland. This will necessarily be informed by targeted research including trials across a range of sites in the greater Barcaldine region. The section below outlines a model developed by Sunshot Industries to establish new practises by combining trial plantations with new research into land carbon stores.

Trial plantations for biomass feedstock

Plantations will be trialled at Rosebank if available or otherwise elsewhere to provide the BREZ biomass feedstock requirements to remove reliance on prickly acacia when required. Plantation rotations will be scheduled with varying harvest years. Most will be short rotations, but some woody species will provide long rotation biomass of over 25 years. Blue Agave (*Agave tequilana*) has been targeted as a suitable pyrolysis feedstock for Renergi with a liquid by-product that is valuable as an input into stock feed or chemical manufactures.

Following initial harvest, it is estimated that 8,950 hectares planted on rotation can supply all of the 145,000 tonnes BREZ annual biomass requirement. It will be a valuable economic activity in itself, with potential for large-scale expansion.

A proposed harvesting schedule is outlined in Table 7 demonstrating a model that can provide low-cost biomass from plantations and optimise prickly acacia harvesting from near and remote locations across the central western area.

CASE STUDY

Barcaldine Productive Plantation and Land Carbon Research and Development Model

Rosebank is the Longreach former pastoral college situated in Longreach, 100km west of Barcaldine. Over 16,000 hectares worth of land, the state-owned facility has a long history of livestock management, horse breeding and sheep and wool training. In 2019 the college closed its doors, and a new use of the land has yet to be found. The site has a great array of facilities geared for livestock research, vegetation trials, facilities for testing the effects of variations in water inputs on productivity, and long-term land and vegetation records that can be used for supporting new research.

A large proportion of Rosebank's 16,000 hectares has been used for grazing, with around 70% covered in Mitchell grass. The site therefore provides opportunities for using restorative grazing methods to increase farm productivity in conventional products while increasing carbon in soils. The remaining areas provide opportunities for carbon farming and sustainable harvesting of biomass.

Subject to receiving all State approvals and support necessary for the BREZ, Sunshot Industries will develop a proposal to submit to the Queensland Government to use Rosebank to demonstrate new types of land-use alongside existing farming systems. Trial plantations alongside grazing paddocks interspersed with different species will be used to assess viability of biomass feedstocks, including for biochar and agave juice production. Here we outline a base-case multiuse scenario for Rosebank involving 8,000 hectares dedicated to beef production, 7,000 hectares for Agave plantation and 1,950 hectares for woody tree plantation, underpinning a research test site for land carbon management. The model for Rosebank involves reinvestment of revenues from grazing and biomass to support new research methodology development including:

- carbon measurement of land-based bio sequestration including biochar across pastoral and agricultural systems, soil carbon, productive plantation and reafforestation and regenerative land management including shelter belts and wind breaks.
- methane reduction methods for livestock using biochar feedstock additive trials and Mitchell Grass grazing management.
- efficacy of slow-release biochar urea pellets fertiliser trials

Figure 23: Land Carbon Research Key Elements

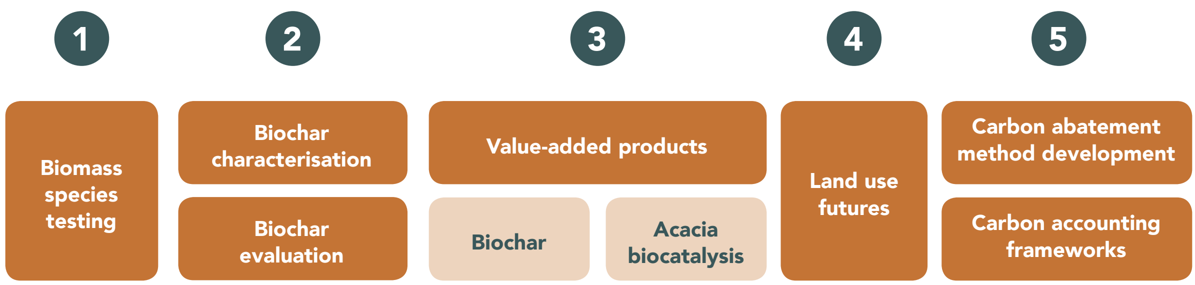


Table 7: Biomass Resource Harvesting Scenario Schedule outline below

			Feedstock quantity (thousand tonnes)															
Feedstock source	Area (Ha)	Irrigation (ML)	Y1-10	Y11 (woody feedstock planting starts)	Y12	Y13 (Agave planting starts)	Y14	Y15	Y16	Y17	Y18	Y19	Y20	Y21	Y22	Y23	Y24	Y25
Agave (planting y13)	1400	0	0	0	0	0	P	P	P	134	0	P	P	P	134	0	P	P
Agave (planting y14)	1400	0	0	0	0	0	0	P	P	P	134	0	P	P	P	134	0	P
Agave (planting y15)	1400	0	0	0	0	0	0	0	P	P	P	134	0	P	P	P	134	0
Agave (planting y16)	1400	0	0	0	0	0	0	0	0	P	P	P	134	0	P	P	P	134
Agave (planting y17)	1400	0	0	0	0	0	0	0	0	0	P	P	P	134	0	P	P	P
Woody Feedstock (y11)	350	700	0	0	0	0	0	0	0	17	0	0	0	0	0	0	17	0
Woody Feedstock (y12)	350	700	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	17
Woody Feedstock (y13)	350	700	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0
Woody Feedstock (y14)	350	700	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0
Woody Feedstock (y15)	350	700	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0
Long rotation Voody Feedstock (y0)	200	400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Native Secrets waste biomass			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Prickly Acacia Harvest			145	145	145	145	145	145	145	0	0	0	0	0	0	0	0	0
Total feedstock			149	149	149	149	149	149	149	155	155	155	155	155	138	138	155	167
BREZ Requirements			19	145	145	145	145	145	145	145	145	145	145	145	145	145	145	145
Cumulative Excess feedstock			130	133	137	141	144	148	152	162	172	182	192	203	196	189	199	220
Total area (ha)	8950																	
Total irrigation (ML)		3900																

Rainbow Bee Eater will purchase partially dry woody biomass feedstock at $45 per metric tonne for bio-char production. Plantation of suitable species (as listed in Table 8) will be trialled at other sites near Barcaldine to demonstrate how yield and productivity varies with soil types across these two main bioregions[10]. Trials will also assess additional native species such as Poplar Box, Boree, Whitewood, Cork wood or Emu apple. Vegetation types vary across the Barcaldine-Longreach area depending on soil type. Many tree species are unable to establish roots in the heavy, cracking, deep clay soils in the Mitchell grass bioregions, but favour the red, sandy, shallow soils of the Desert Uplands bioregion. A native wattle with high seed volumes and short life may fit well into a system that contributes value through growth of carbon in trees in the early stages of plantation growth, wattle seed for sale through its mature life, and biomass for pyrolysis on a rotating basis with replanting at end of tree life. Trials of biodiverse plantings will be tested for value, taking into account eligibility for biodiversity credits. Trial plantations will use saplings sourced from a new local nursery and from a Brisbane-based Agave nursery.

Agave and some other species do not require irrigation, but plantations of some species under consideration will perform better with on average 2ML of water per hectare per year supplied through drip irrigation systems. Sunshot is actively engaged in discussions with Barcaldine and Longreach Councils on utilisation of wastewater from sewerage and with the Queensland Government for access to any water that might be available commercially under existing water plans in the region. There are some possibilities for irrigated biomass plantings in the wetter country in the east of Barcaldine Shire Council, in the catchment of the Belyando River (a tributary of the Burdekin).

Apart from irrigation, water for the Barcaldine Renewable Energy Zone (BREZ) will be sustainably sourced from GAB aquifers. Negotiations are underway to partner with the Queensland Department of Regional Development, Manufacturing and Water (DRDMW) to identify existing free-flowing bores on private land, that Sunshot Industries will cap and rehabilitate to access a proportion of the water for the BREZ. Rehabilitating free flowing bores will save significant quantities of water that are currently being lost from the GAB due to seepage and evaporation from uncapped bores and/or free-flowing bore drains. Partnerships with DRDMW and landholders also prevents the need to drill additional bores into the GAB. This process to source water was chosen as it will have the least impact on the GAB and the nearby fragile artesian springs, and it is anticipated that access to water via this method will be cost-effective.

Detail of the financial opportunity of biomass growth and land carbon value stacking is summarised in the Breakout Box: Financial opportunities for `value stacking` land carbon.

[10] The Bioregion 'Desert Uplands'; the red sandy shallow earths of where Barcaldine is situated, flanks the undulating ranges of the Brigalow Country and the cracking deep clay of the West. The region is thickly vegetated, marked by sandstone ranges and sandplains. The heavy cracking, deep clay west of Barcaldine, is characterised as the Mitchell Grass Downs bioregion which stretches out into central NT. Almost 100% of the Mitchell Grass bioregion is grazed.

Figure 24: Map showing the Bioregions of Queensland

FINANCIAL OPPORTUNITIES FOR 'VALUE STACKING' LAND CARBON

Sunshot Industries has prepared a preliminary financial analysis of a working farm system that demonstrates `value stacking` of land carbon in the Barcaldine region.

The analysis compares two cases. The base case assumes revenue from beef production over 8,000 hectares at Rosebank, 7,000 hectares of Agave plantation and 1,950 hectares of woody tree species including across private land around Barcaldine. Carbon credits are assumed at $20 for aboveground biomass from Agave and Woody tree species. At 150 tonnes of CO2e at time of harvest annual revenue would be $270, considering a 10% reduction due to administrative fees and ERF carbon payback risk allocation. While the carbon credit does not currently exist due to methodological restrictions under the Plantation Forestry method of the ERF (see Lessons section), it is estimated to draw down 1.3 million tonnes of CO2e every 10 years.

A second scenario includes Biochar carbon credits priced at $100/tonne of CO2e sequestered applied to 20% of the soil at Rosebank. The estimates of the net-present value for the three cases are strongly positive on the assumption that a move to comprehensive carbon accounting would reward increases in carbon stocks. The research at Rosebank would be designed to test the profitability of alternative farm management systems when carbon value features in revenue streams.

The results would be used to demonstrate to the Commonwealth the case for movement to comprehensive carbon accounting, and to farmers of the value of taking carbon value into their business investment decisions once they are confident that accretion of carbon will be rewarded in an environmentally efficient way.

Table 8: Trees and plants selected for productive plantations in variable rainfall conditions in the Central West Queensland region

Species	Native status	Characteristics	Adult Growth rate	Added-value products	Current use	Irrigation required
Gundabluey / Elegant Wattle (Acacia victoriae)	Yes	Drought tolerant. Commonly in clay or loam on alluvial flats. Acacia victoriae is also a good windbreak and useful for soil stabilisation. Rapid growth flowering in 2 years.	2 years	Seed used for bush tucker and flour. Soil stabiliser.	Wattle seed production.	Yes – low
Shoestring Acacia (Acacia stenophylla)	Yes	Drought tolerant. Growing on a wide range of soils including heavy clays.	3 years	Soil regeneration. Potential to be grown in agroforestry with pastures.	Timber and craftwood. Windbreaks. Mine-site rehabilitation.	At planting then Low – nil
Pongamia (Millettia pinnata formerly Pongamia pinnata)	Yes (naturalised)	Prolific seed production. Up to 9000kg seeds/ha. Seeds contain 40% oil. Low weed risk. Drought tolerant. Zero input requirements.	4-5 years	Biodiesel. Soil Stabiliser. Indigenous medicine.	Animal fodder. Garden Ornament.	Low-medium irrigation
Agave (Agave tequiliana & A. americanum)	No	Drought-tolerant. Requires hot climates. Lifespan between 8-14 years.	5 years until harvest	Tequila from the tequilana variety. Squeezed for molasses.	Ethanol development. Tequila and Mescal in Mexico.	No
Old Man Saltbush (Atriplex nummularia)	Yes	Can grow in saline conditions. Lifespan 10-20 years. Expensive and difficult to establish. Extremely long lived >100 years	Can be grazed within the first year	Supplementary stock feed	Supplementary fodder in Autumn time. Fodder in salinated areas.	At planting then nil

Land carbon sequestration

Awareness of benefits of increasing soil carbon in soils has grown considerably over the last few years. Soil carbon management is essential to restorative agricultural practises and the lift they can provide to land productivity. The development of voluntary and mandatory carbon markets in Europe and North America and the business search for carbon offsets to achieve zero-emissions commitments have driven Australian entrepreneurial interests in carbon farming. There is early understanding in rural and provincial Australia of the potential for production of bio-char for soil management.

As recognised by the Intergovernmental Panel on Climate Change (IPCC) bio-sequestration currently provides the most cost-effective methods of carbon drawdown (negative emissions). Increasing soil carbon stores through reafforestation, productive plantation management, bio-char addition and regenerative land management will be required at significant scale to meet Paris Agreement targets.

Absorption of carbon in soils is one of the Federal Government's Low Emissions Technology Roadmaps' five priority technologies. The roadmap saw sequestration potential of 35 to 90 million tonnes per annum of carbon dioxide. According to the Roadmap low-cost measurement technologies will unlock commercial potential, with the goal bringing costs down to $3 per hectare.

The Land Carbon Model will trial three methods of bio-sequestration:

- **Biochar -** Pyrolysis can be used to convert biomass into a combination of pure carbon or char and liquid or gaseous hydrocarbons. Char is used to increase moisture retention contributing to improved productivity. When returned to the soil char can fix carbon for many hundreds to thousands of years. As a soil additive, it attracts biota that are instrumental in augmenting the soil carbon store. As a food supplement for ruminants, it leads to more complete digestion of food thereby reducing methane emissions per unit output and, passed through in manure, adds to the soil carbon store.
- **Productive plantations -** Plantations for biomass for industry offer effective carbon sequestration at scale as they are fast growing, harvested and replanted using crop rotation. During the initial fast growth period carbon is sequestered. Once a given area is being harvested and replanted, growth of replanted trees balances loss from harvesting. Following harvest, the biomass is converted in part to biochar storing carbon permanently.
- **Reafforestation and regenerative land management -** Farm restoration activities such as complex regeneration or regrowth, shelter belts and wind break and environmental biodiversity and riparian planting, deliver co-benefits that in addition to reducing land stress and improving overall productivity and carbon sequestration pathways, they deliver discrete carbon accretion that can be measured and rewarded.

Rigorous certification of bio-sequestration methods is needed to support participation in voluntary and official international carbon markets. The development of credible methodologies is a pre-condition for large-scale entry into these markets. There is a need to identify practices that provide measurement, monitoring and verification (MMV) for both greenhouse gas land sector emissions and land carbon stores at the scale of individual business units. The development of robust low cost MMV methods is needed not only to increase uptake of these practices but also to strengthen public trust and support for future carbon farming policies.

There is growing recognition that remote sensing technologies can significantly reduce the costs of MMV in land sector bio-sequestration applications, which will facilitate greater participation of landowners in the Australian Emission Reduction Fund and in voluntary carbon markets. Significant R&D is required, focussed on methodologies that landowners can adopt across a range of bio sequestration (productive plantations, biochar, vegetation management, reafforestation, and soil carbon). The goal is greatly to reduce the costs of participation in carbon trading, through Geospatial and Lidar mapping, improving efficiencies in survey design and ground truthing of generalised or developed allometric models.

To this end, Sunshot proposes to use the trial sites for testing, development and improvement of carbon accounting methodology developed by the CSIRO team led by Dr Keryn Paul. If available, the Rosebank site would offer excellent scope for improving accuracy of carbon sequestration following land restoration activities, including restoration from degraded lands and riparian zones and the establishment of environmental and commercial plantations. New and existing datasets will be collated to improve accuracy of prediction of abatement from various management options for plantations and farm forestry projects and natural regeneration in rangelands and semi-arid woodlands and shrublands.

The BREZ Land Carbon Research initiative (LCRI) is envisaged as a collaboration between multiple research agencies. Research partners include CSIRO, QUT, ANU and UoM and implementation partners include The Carbon Farming Foundation, private local landholder and olive oil producer Cobram Estate, and other large-scale local pastoralists. Work with CSIRO, QUT will also trial and verify methods for methane reduction and efficacy of slow-release fertiliser for nitrogen emission mitigation and improved absorption (volatilisation reduction). Meat and Livestock Australia and QUT have already made significant progress on methane reduction and verification and the grazing trials of the LCRI combined with the CSIRO bio-char characterisation work will support these studies.

The BREZ LCRI will facilitate demonstration of potential co-benefits of carbon farming such as the value of mosaic landscape practices. A mosaic landscape builds a range of tree and vegetation cover that address issues of monoculture plantations, including issues of resilience and sustainability in the face of changing climate and biodiversity loss[11].

One focus of the LCRI research will be to test and suggest new carbon abatement methodologies for the Australian ERF, that have high environmental integrity and expand incentives for their use on Australian farms.

Supply of carbon credits is inhibited by many arbitrary restrictions in the current Emissions Reduction Fund. One that is relevant to the central west of Queensland is geographical restrictions placed on forestry plantations. Under the ERF Farm Forestry methodology, up to 300ha of land, or less than 30% of a farm area, whichever is smaller, will be allowed carbon credits for areas outside of the National Plantation Inventory. The National Plantation Inventory regions include the coast of QLD, NSW, Victoria, around the Green Triangle in SA, the Southwest of WA and the Top End of the NT. This means that many parts of Queensland including Barcaldine and the central west are limited to a small area of potential accreditation. Changes to include land outside the NPI regions have been restricted due to lack of data on yield estimates and understanding baselines to calculate 'additionality' in these zones. By demonstrating yields and carbon increases in these regions with value stacking systems such as the LCRI model, we demonstrate missed opportunities for carbon sequestration. With lower productivity and rainfall in the arid and pastoral rangelands, and the careful selection of high yielding biomass crops, there are large gains to be made across a very large expanse of regional Australia.

The BREZ looks to the inclusion of low-rainfall zones in the ERF plantation forestry methodology to apply for the Land Restoration Fund. The BREZ will demonstrate its commitment to biodiversity and socioeconomic benefits in this application.

For bioenergy projects, carbon stored in growing plants increases until the plantation is harvested at a high rate. From that time, new trees are planted as mature ones are harvested, so that the combustion of biomass is offset by the sequestration of carbon in new growth. The net result is emissions neutrality from the time the plantation reaches its maximum living biomass. In the BREZ system there is further storage of a percentage of this carbon into the soil as biochar. This provides continuing net negative emissions. Biochar is now a lucrative negative emission technology on the international voluntary carbon

[11] https://www.climateextremes.org.au/el-nino-southern-oscillation-enso-risks-for-western-australian-graziers/

market, through which the BREZ will receive high quality carbon credits when used on fields in the surrounding farms.

One aim of the LCRI research project will be design of a bioenergy carbon credit, that measures carbon across the whole life cycle of the biomass including growth of biomass, transportation and fuel use, combustion of bioenergy and storage of biochar in soil either as a stock feed or soil amendment. This credit will include direct Land Use Change (dLUC) emissions from transformation of grazing pasture into productive plantation. We aim to demonstrate a positive net carbon store from this dLUC as calculated under ISO standard Life Cycle Assessment.

Carbon credits will also be sought for trees in similar longevity to the Human Induced Regeneration (HIR) methodologies and Reforestation by Environmental or Mallee plantings. This will form a range of carbon sequestration designs over LCRI sites. These designs will inform policy and methodology development associated with LCRI research intentions of the Biomass model (outlined in Section 6). These above-ground accretions will be carefully monitored by CSIRO's Geo-spatial group under Dr Shaun Levick and soil carbon will be monitored by QUT's Professor Peter Grace.

A new methodology called Comprehensive Carbon Accounting will be trialled in LCRI under these conditions by Professor Ross Garnaut of the University of Melbourne and Professor Andrew Macintosh of ANU. This has been discussed in Barcaldine with the Commonwealth Minister for Agriculture.

Carbon Regulation Reform: moving towards Comprehensive Carbon Accounting

Reform of the Australian carbon accounting and trading rules is necessary for landscape carbon to make its full potential contribution to climate change mitigation and economic development. There are four problems in the current arrangements. First, the ERF's methodologies do not relate systematically to the objective of rewarding landowners for contributions they make to sequestering carbon. Second, measurement costs are unnecessarily high, reducing incentives for participation in carbon sequestration, especially for small producers. Third, the market arrangements hold prices well below the social cost of carbon—and below rewards for carbon sequestration in countries that seek to reward carbon reduction at its social value, notably the European Union, the UK and other countries in Europe. Fourth, incentives to manage land to increase carbon stocks need to be balanced by other mechanisms for securing other values, notably biodiversity, that currently are not rewarded in private market exchange.

Let's look at the first of the necessary reforms: movement towards what we have called comprehensive carbon accounting in providing incentives for increasing the amount of carbon in soils and plants.

What matters for global climate is the total amount of carbon stored in the soil and plants. The methodologies developed by the Clean Energy Regulator are simply means to ensure that incentives are provided for real increases in carbon stocks. They are partial approaches, and approximations of the reality. Movement in the world and in Australia towards a comprehensive approach to rewarding owners of land for increases in carbon stocks and penalising them for reductions will have both environmental (climate) and economic development advantages for Queensland, Australia and the world.

Australia as the developed country with proportionately by far the largest opportunity per capita for sequestering carbon in the landscape, and for dealing scientifically with the issues, has a strong interest and capacity in leading the development of comprehensive approaches to accounting and providing incentives for increases in carbon stocks. Now, with the international community making concerted efforts to deal with climate change, is the time to move towards comprehensive accounting of changes in plant stocks in soils and plants.

Ideally, Australia would establish a baseline for carbon stocks and reward all increases and penalise all reductions from that baseline. The baseline would have to have integrity. Much of the current complexity in methodologies for accrediting increases in carbon stocks derives from attempts to secure "additionality"—to ensure that the increase in stocks to be rewarded are increments above what would have happened anyway. The objective is an important one. However, it is in its nature highly subjective and therefore impossible to measure: what is additional to what would have been done without reward depends on what is in the mind of the landowner. One landowner might recognise that restorative farming increases fertility and agricultural value independently of rewards for increases in carbon stock. Current approaches to incentives for land carbon sequestration seek in principle to exclude a farmer with these things in her mind, while rewarding a farmer that does not recognise the commercial value of restorative farming. This is impractical. It is also beside the point. The additionality that matters and which should be secured is the genuine addition in sequestered carbon from stocks at a clearly defined time.

The baseline has to be set at a time no later than the announcement of the new arrangements- to remove incentives to denude carbon stocks early, so as to increase the opportunities for increasing carbon stocks that are rewarded. That baseline could be set at a date early this year. A landowner seeking to enter comprehensive carbon accounting arrangements would have the carbon stocks in the soil and plants measured at the earliest feasible date, be required to certify that there had been no material degradation since that base date and be accountable for any denudation that was later identified by the regulatory agency responsible for managing the accounting scheme.

The landowner would choose whether or not to enter the arrangements, at least until such time as an overwhelming proportion of Australian land was being managed within comprehensive carbon accounting. Having chosen to enter the scheme, the landowner would face reciprocal obligations: enforceable obligations to pay for reductions in the carbon stock would accompany opportunities for reward from increases in carbon. Private or official insurance and averaging arrangements would be developed to provide buffers against short term variations from cyclical climate conditions or unexpected events.

Leasehold land and Indigenous title raise special issues that need to be considered. Decisions have to be taken amongst alternative approaches.

The accounting period could cover multiple years, with remote sensing or other indirect techniques applied to measure stocks of carbon below and above the ground at low cost. The new scheme, like the Emission Reduction Fund, would be administered by the Commonwealth's Clean Energy Regulator. Landholders' decisions on whether to opt in or out would be supported by provision of advice and upfront consultation.

Strong focus on the environmental integrity of the arrangements would be crucial in persuading the international community into an environmentally and economically efficient approach to accounting and providing incentives for an increase in carbon stocks in plants and soils

The second problem is the current high cost of measurement. This makes the transactions costs of carbon trading almost prohibitive for small participants. Traditional methods depend on physical sampling and laboratory testing of soils and measurement of trees and other plants. This inevitably involves intensive use of labour, including some with valuable skills, and transport of people and materials. Fortunately, reliable, less expensive alternatives now exist for measurement of carbon in soils and plants and also for measurement of biodiversity. These involve indirect measurement, including remote sensing from drones or satellites.

The challenge is to build confidence in the alternative measures, by systematic comparison of results from physical and remote sensing measurement. The Commonwealth Government began to invest substantial resources into reducing the cost of carbon measurement in the process of developing the Low Emissions Technology Roadmap in 2020. This focussed initially on reducing the cost of measuring carbon in soils. Recent developments include Commonwealth support of technologies for remotely measuring biodiversity, variations on which can be applied to measuring carbon in plants. It is important for Queensland and for Australia as a whole that this work be completed quickly, to reduce the cost of measuring carbon stocks in soils and plants as comprehensive carbon accounting is introduced.

The third problem is the limited demand for Australian carbon credits and the associated low price. The true value of sequestered carbon is the price which will encourage enough reduction of carbon emissions and enough sequestration of carbon to meet the agreed international objective of zero emissions by mid-century. If the international community set limits on total carbon emissions that were consistent with steady progress from now towards zero emissions by 2050, the market would set the price that would define the social value of carbon sequestration. Modelling for the Federal, State and Territory governments of Australia that was published in the Garnaut Climate Change Review in 2008 suggested that the price then would have been a bit above $A40 per annum, rising at an interest rate about 4 percentage points above the rate of inflation. That would amount to about double that price today. Since then, a decline in global interest rates would have raised the equivalent current price and lowered the rate of increase; and reductions in costs of zero emissions technologies may have lowered the price that the market would set. The Obama administration in the US required the Department of Energy to publish an estimate of the social cost of carbon. The Department of Energy's central estimates turned out to be close to those from the 2008 Garnaut Review. The European Union's Emissions Trading Scheme price is currently about 63 Euros per tonne of carbon dioxide or around $100 in Australian dollars (or around $350 per tonne of carbon). The IEA has recently suggested that a carbon price of around $US70 per tonne (or $A100) of carbon dioxide would be required by 2030 to deliver zero net emissions by 2050. The social cost of carbon established around the Paris climate change mitigation goals can be taken to be somewhere near the current European price.

A true value of carbon sequestration of around $A100 per tonne of carbon dioxide that rises over time is over six times higher than the average price for Australian Carbon Units (ACCUs) that has emerged from auctions from the Australian Emissions Reduction Fund and its successor, the Climate Solutions Fund. It is four times higher than the higher price for Australian Carbon Credit Units (ACCUs) that has emerged recently. The Australian official market is highly restricted and artificial. Sales mostly depend on purchases of defined quantities by the Australian Clean Energy Regulator. The volume of sales has been linked neither to international carbon market nor to the requirements of Australia's obligations under the Paris Agreement to reach zero net emissions by 2050. It is an artificial price which can be expected to rise over time to international levels, reflecting the social cost of carbon.

At a price like $70 per tonne (which would be one third below current prices in the European Emissions Trading System), an immense land carbon industry would emerge in Australia, offsetting emissions in other sectors where costs of abatement exceeded that level, and supplying overseas markets. The overseas markets would emerge first through companies' private and voluntary commitments to achieve zero emissions, and later from negotiation of Government-to-Government arrangements that secured Australian access to the compliance markets of countries with firm decarbonisation commitments. Australian access to voluntary markets and to compliance markets comprehensively require decarbonisation commitments comparable to those of other developed countries—zero net emissions by 2050. Understanding that Australia has arrangements in place reliably to achieve those goals will be importance for the confidence of Australian trading partners

Carbon sequestration can't be sold twice. At home, a single carbon unit cannot be used both to offset one company's domestic emissions and for sale into an international carbon market. Abroad, it cannot be used by a company to offset its own emissions, and to generate revenue by sale of ACCUs.

Australia is currently a long way from meeting the conditions for deep integration into international carbon markets. We can nevertheless make a start on developing a carbon farming industry with stronger demand and higher prices than have been generated by Government purchases through the ERF. A first and essential step is reform of carbon accounting as suggested in this report, accompanied by diplomatic effort to influence the development of environmentally and economically efficient international rules. The larger challenge is to expand the market, to support the lifting of prices towards the social cost of carbon. Larger appropriations from the public revenue would help, but indications so far are that the annual rate of public budgetary commitment will be lower in the 2020s than over the past half dozen years. A more important step would be mandatory requirements for Australian producers of fossil energy to offset fugitive emissions. Several of the larger established Australian LNG and coal exporters are currently committed to zero net emissions by specified dates on various timetables with completion by or before 2030. Companies which have not made such commitments are under pressure from investors, lenders and the broader community to do so—and will come under pressure from environmentally responsible gas and coal companies who otherwise will be placed at a competitive disadvantage against firms who have made no commitments.

The integration of Australia into valuable international carbon markets would assist the emergence of plant production for biomass as a base for industrial production. Vegetation stocks could rise to levels at which harvesting and replanting becomes viable without diminution of carbon stocks. Biomass would become available to support a range of industrial and energy production, as discussed earlier.

The arrangements suggested here would see carbon markets rewarding landowners for their contribution to carbon sequestration. The increase in private reward for storing carbon could exacerbate undervaluation of a number of other environmental services that wise consideration recognises as being important to human as well as environmental amenity. This makes it important to introduce separate markets for biodiversity and some other environmental values, funded by Government or by private voluntary exchange. There has been recent progress on biodiversity credits, for example with Queensland's Land Restoration Fund, and with the Commonwealth Minister for Agriculture's efforts to develop biodiversity credits to sit alongside and to augment incentives for carbon sequestration.

These developments are potentially of large importance for Australian economic development. They are proportionately more important for Queensland than for other Australian states. Queensland has an immense interest in working with the Commonwealth to secure progress where possible. So long as the Commonwealth continues to develop the regulatory framework, Queensland on its own or with some or all of the States can introduce requirements for offsetting fugitive emissions by purchase of ACCUs from the domestic farm sector.

A special BREZ opportunity

The production in the same location of urea and char opens a possibility for development of a slow-release nitrogenous fertiliser that would have high value in regions subject to flooding rains—including much of Queensland. Laboratory experiments suggest that urea embedded in char to form a pellet leads to slow release of the urea, even in the temporary presence of large amounts of water from rain. The mixture of urea and char in many circumstances is especially valuable for agricultural productivity in the immediate and especially the long term. Slow release of nitrogenous compounds in heavy rain reduces waste of fertiliser. It also reduces run-off into streams and rivers—and from coastal sugar farming and horticulture, into the Great Barrier Reef lagoon.

The availability of biochar and zero emissions ammonia and urea at Barcaldine may warrant the Department of Environment and Science encouraging development of a slow-release nitrogenous fertiliser, for its environmental and economic advantages in Queensland. Sunshot Industries and its partners in BREZ would welcome interest in this opportunity.

Lessons for Queensland Regions in Transition

Government policy settings:
key initiatives and incentive

Building Industrial Precincts

The emergence of new manufacturing industry in rural and provincial Queensland requires the co-location of facilities and inputs for processing minerals and biomass and other industrial activities, including low-cost electricity and hydrogen.

A successful Industrial Precinct, as demonstrated by the Barcaldine model, provides the full range of services necessary for manufacturing: multi-modal transport (as many as possible of port, road, rail and air); electricity and sources of heat energy (hydrogen, and heat output from exothermic processes located within the Precinct) at internationally competitive prices; water; and ease of internal transfer of materials and energy as each projects waste becomes another's feedstock. The wider the range of related investments, the more attractive the Precinct for additional activities. The processing and use of biomass have many valuable linkages to other industries and it is an advantage if this is present in a Precinct.

Planned, integrated Precincts are more important in new and isolated industrial regions than in a great and old city. In the established industrial city, supply of a wide range of services and industrial inputs is available through competitive market processes, by incremental expansion of established systems. In new industrial regions the state must play a leading role in coordinating the early stages of development.

Development in rural Queensland faces a number of cost disadvantages that are only likely to be overcome by using the immense potential for low-cost electricity and biomass. Our work has led us to the following recommendations: two relate to development of decentralised industrial precincts; three relate to use of rural Queensland's immense capacity to produce low-cost electricity; and seven relate to the use of rural Queensland's immense land and water resources to produce large quantities of carbon credits and biomass within a broader framework of integrated regional development.

Recommendations

On Decentralised Industrial Precincts:

1. In general, overcome the disadvantages of small scale and isolation from major centres of industrial activity by developing Precincts of diverse industrial activity with access to globally competitive power and good infrastructure services.

2. In particular, identify locations for and provide initial funding of studies on a small number of Sustainable Development Precincts, based on access to established transport and other infrastructure, location in relation to biomass, renewable energy and minerals resources, other aspects of economic opportunity, and local interest. Barcaldine is the first. It is suggested that Longreach, Hughenden, Emerald and several possible sites in the Darling Downs and Morandah in the Bowen Basin are promising candidates for evaluation. Funding for evaluation of the kind provided for the current study of Barcaldine can be important to focussing private attention and investment on evaluation of rural industrial precincts. Sunshot Industries and its partners have spent many times the amount of funding provided through the Department of Environment and Science Communities in Transition program for the work in Barcaldine. However, the grant funding was of large importance in the company and its partners taking the decision to proceed into detailed evaluation of the prospects. It would not have happened without that material demonstration of Government support.

On renewable energy infrastructure and regulation:

3. Ensure that Barcaldine's inclusion as one of the Queensland Renewable Energy Zones leads to timely and cost-effective connection of the BREZ and the wind and solar farms to the Ergon network centre and the high voltage transmission line joining Barcaldine to the main grid near Clermont.

4. Ensure that the relevant Queensland Government agencies and enterprises examine the role that substantial upgrading of the transmission connection from Barcaldine to the main grid could have in underwriting industrial growth along the route and especially at Gladstone; within a larger evaluation of the role that subsequent high voltage transmission from Hughenden to Barcaldine could play in underwriting industrial development in a Rhombus of Reliability serving Gladstone, Townsville, Hughenden, Barcaldine and the large area of central and north Queensland within its boundaries.

5. Examine two regulatory changes that would greatly accelerate Queensland's emergence as a Superpower of the low carbon world economy:

   (i) Treating electrolysers as balancing assets akin to batteries for transmission pricing within the electricity system.

   (ii) Introducing dynamic calculation of Minimum Loss Factors for access to constrained transmission lines, so that the high loss factors are not applied when lines are not constrained and are capable of transmitting power into the grid from batteries or other sources when this would be helpful to stability and price moderation throughout the system. In areas where low MLFs are driven by surplus solar power in daylight hours, the MLFs would be adjusted to allow for the absence of congestion through the evening, night and early morning.

On use of land for carbon credits and industrial biomass:

6. Support research to define and utilise Queensland's natural advantages in growing biomass for industry and storing carbon in soil and plants: research into species and methods with joint research amongst Commonwealth (principally CSIRO), Queensland agencies and Universities. Engage CSIRO in research and Commonwealth in support for research to focus on bio-sequestration and production of biomass in Central West Queensland.

7. Work with the Commonwealth to reform carbon accounting and regulation towards implementation of comprehensive carbon accounting.

8. Work with the Commonwealth and other States towards introduction of mandatory requirements for offsetting fugitive emissions from fossil carbon production.

9. Work with the Commonwealth in expanding access to international voluntary and compliance markets for Australian land-based offsets.

10. Engage national Indigenous and Commonwealth funding institutions in evaluating investment in Queensland landscape carbon.

11. Continue the work of the Queensland Land Restoration Fund, and work with the Commonwealth to extend funding arrangements to provide incentives for biodiverse growth of biomass.

12. Encourage and support the development of local production of slow-release nitrogenous fertilisers embedding ammonia compounds in char, to improve productivity of fertilisers and reduce runs-off into waterways and the Great Barrier Reef Lagoon.

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